Screening For Environmental Concerns At Sites With Contaminated Soil and Groundwater

Volume 1: Summary Tier 1 Lookup Tables

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DISCLAIMER

This document, *Screening For Environmental Concerns at Sites With Contaminated Soil and Groundwater* (Interim Draft, December 2003), is a technical report prepared by staff of the Hawai'i Department of Health, Environmental Management Division, with assistance from Roger Brewer the California San Francisco Bay Regional Water Quality Control Board. It is intended to serve as a supplement to the 1996 HIDOH document entitled *Risk-Based Corrective Action and Decision Making at Sites With Contaminated Soil and Groundwater.* This document is not intended to establish policy or regulation. The Environmental Action Levels presented in this document and the accompanying text are specifically not intended to serve as: 1) a stand-alone decision making tool, 2) guidance for the preparation of baseline ("Tier 3") environmental assessments, 3) a rule to determine if a waste is hazardous under the state or federal regulations, or 4) a rule to determine when the release of hazardous chemicals must be reported to the overseeing regulatory agency.

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Executive Summary

This document presents Environmental Action Levels (EALs) for chemicals commonly found in soil and groundwater at sites where releases of hazardous chemicals have occurred. The EALs are intended to serve as an update and supplement to the Hawai'i Department of Health (HIDOH) document *Risk-Based Corrective Action and Decision Making at Sites With Contaminated Soil and Groundwater* (June 1996). The change in terminology from "Risk-Based Action Levels" to "Environmental Action Levels" is intended to better convey the broad scope of the document and clarify that some action levels are not "risk-based" in a strict toxicological definition of this term. Use of the EALs is not mandatory. The document may especially be beneficial for use at sites with limited impacts, however, where preparation of a detailed environmental assessment may not be warranted or feasible due to time and cost constraints.

The EALs are considered to be conservative. Under most circumstances, and within the limitations described, the presence of a chemical in soil, soil gas or groundwater at concentrations below the corresponding EAL can be assumed to not pose a significant, long-term (chronic) threat to human health and the environment. Additional evaluation will generally be necessary at sites where a chemical is present at concentrations above the corresponding EAL. Active remediation may or may not be required, however, depending on site-specific conditions and considerations.

The EALs were developed to help address the following environmental goals:

Groundwater Quality:

- No adverse impacts to drinking water resources (toxicity and taste & odors)
- No adverse emissions to indoor air
- No discharges to surface water greater than chronic surface water goals
- No discharges to surface water that may pose nuisance concerns (odors, sheens, etc.)
- Minimize gross contamination (no free product, resource degradation, etc.)

Soil Quality:

- No chronic health effects to residences and/or workers (occupational, industrial, construction, etc.)
- No leaching and adverse impacts to groundwater
- No adverse emissions to indoor air
- No adverse impacts to important flora and fauna
- No nuisances (odors, aesthetics, etc.)

Primary EALs for soil and groundwater are summarized in two lookup tables. Each table reflects a specific designation of groundwater utility and location with respect to the nearest body of surface water. A detailed review of environmental concerns addressed

by the action levels is provided in Appendix 1. Groundwater action levels specific to drinking water concerns and aquatic habitat protection are provided in separate tables for use on a site-specific basis. Additional soil action levels are presented for areas of high rainfall (<200cm/year).

As described in the 1996 HIDOH document, the action levels are intended to be used in a "tiered" approach. Under "Tier 1", sample data are directly compared to EALs selected for the site and decisions are made regarding the need for additional site investigation, remedial action or a more detailed risk assessment. In a "Tier 2" risk assessment, a selected component(s) of the Tier 1 EAL is modified with respect to site-specific considerations. An example may be the adjustment of a screening level for direct exposure with respect to an approved, alternative target risk level. Site data are then compared to the revised screening level as well as the remaining, unmodified components of the Tier 1 EAL. This provides an intermediate but still relatively rapid and cost-effective option for preparing more site-specific risk assessments. Risk assessment models and assumptions that depart significantly from those used to develop the Tier 1 EALs are described in a more traditional, "Tier 3" risk assessment. The Tier 1 methodology can, however, still provide a common platform to initiate a Tier 3 risk assessment and help ensure that all potentially significant environmental concerns are considered.

The Tier 1 EALs presented in the lookup tables are NOT regulatory "cleanup standards". This document is intended to serve as a supplement to cleanup standards currently presented in the Hawai'I Administrative Rules, Title 11, Chapter 281 (Underground Storage Tanks). Use of the EALs and this document in general is intended to be optional on the part of the regulated facility and subject to the approval of the project manager in the Department of Health. The presence of a chemical at concentrations in excess of an EAL does not necessarily indicate that adverse impacts to human health or the environment are occurring; this simply indicates that a potential for adverse risk may exist and that additional evaluation is warranted. EALs presented for chemicals that are known to be highly biodegradable in the environment may in particular be overly conservative for use as final cleanup levels (e.g., many petroleum-related compounds). Use of the EALs as cleanup levels should be evaluated in view of the overall site investigation results and the cost/benefit of performing a more site-specific risk assessment.

Reliance on only the Tier 1 EALs to identify potential environmental concerns may not be appropriate for some sites. Examples include sites that require a detailed discussion of potential risks to human health, sites where physical conditions differ drastically from those assumed in development of the EALs (e.g., mine sites, landfills, etc., with excessively high or low pH) and sites where impacts pose heightened threats to sensitive ecological habitats. Potential impacts to sediment are also not addressed. The need for a detailed ecological risk assessment should be evaluated on a site-by-site basis for areas where significant concerns may exist.

The EALs should NOT be used to determine when impacts at a site should be reported to a regulatory agency. All releases of hazardous substances to the environment should be reported to the HIDOH in accordance with governing regulations. The lookup tables will be updated on a regular basis, as needed, in order to reflect changes in the referenced sources as well as lessons gained from site investigations and field observations.

1

Introduction

1.1 Purpose

Preparation of detailed environmental risk assessments for sites impacted by releases of hazardous chemicals can be a time consuming and costly effort that requires expertise in a multiple of disciplines, including toxicology, geology, ecology, chemistry, physics and engineering, among others. For small-business owners and property owners with limited financial resources, preparation of such risk assessments can be time and cost-prohibitive.

As a means to partially address this problem, this document presents a series of conservative Environmental Action Levels (EALs) for soil, groundwater and soil gas that can be directly compared to environmental data collected at a site. Correlative action levels for surface water are also provided. Action levels for over 100 commonly detected contaminants are given in a series of "lookup" tables. The tables are arranged in a format that allows the user to take into account site-specific factors that help define environmental concerns at a given property.

Within noted limits, risks to human health and the environment can be considered to be insignificant at sites where concentrations of chemicals of concern do not exceed the respective EALs. The presence of chemicals at concentrations above the EALs does not necessarily indicate that a significant risk exists at the site. It does, however, generally indicate that additional investigation and evaluation of potential environmental concerns is warranted.

The introductory text of this document is kept intentionally brief with a focus on the use of the EALs rather than technical details about their derivation. Technical background data regarding the EALs are provided in the appendices of Volume 2.

1.2 Tiered Approach to Environmental Risk Assessments

This document presents a three-tiered approach to environmental risk assessment. Under "Tier 1", sample data are directly compared to EALs selected for the site and decisions are made regarding the need for additional site investigation, remedial action or a more

detailed risk assessment. A detailed understanding of the derivation of the action levels is not required for use at this level.

Under "Tier 2", selected components of the models used to develop the Tier 1 EALs are modified with respect to site-specific data or considerations. Examples include adjustment of the assumed depth to impacted groundwater in the Tier 1 indoor-air impact model or use of an approved, alternative target risk level for direct-exposure concerns. Site data are then compared to the revised screening level as well as the remaining, unmodified components of the Tier 1 EALs. This provides an intermediate but still relatively rapid and cost-effective option for preparing more site-specific risk assessments.

Under Tier 3, the user employs alternative models and modeling assumptions to develop site-specific screening or final cleanup levels or quantitatively evaluate the actual risk posed to human and/or ecological receptors by the impacted media. Consideration of the methodologies and potential environmental concerns discussed in this document is still encouraged, however. This will help increase the comprehensiveness and consistency of Tier 3 risk assessments as well as expedite their preparation and review.

1.3 Comparison To Existing Action Levels

Soil and groundwater action levels previously prepared by HIDOH are presented in the document *Risk-Based Corrective Action and Decision Making at Sites With Contaminated Soil and Groundwater* (June 1996). In addition, Region IX of the U.S. Environmental Protection Agency (USEPA 2002) prepares and routinely updates risk-based "Preliminary Remediation Goals (PRGs)" for soil, water and air. The lookup tables presented in this document represent a compilation and expansion of this work. Differences and similarities between the 1996 HIDOH action levels and the USEPA PRGs are summarized below. A brief discussion of OSHA "PELs" is also provided.

1.3.1 1996 HIDOH Action Levels

1.3.1.1 Updates to Environmental Concerns

Soil and groundwater action levels presented in the June 1996 HIDOH document addressed the following environmental concerns:

Groundwater Quality:
- Protection of human health
  - Current or potential drinking water resource;
- Protection of aquatic habitats (discharges to surface water);

Soil Quality:
- Protection of human health

- Direct/indirect exposure to impacted soil (ingestion, dermal absorption, inhalation of vapors and dust in outdoor air);
- Protection of groundwater quality (leaching of chemicals from soil);
- Maximum levels (theoretical saturation limits for liquid chemicals).

This document presents a comparable set of action levels for the above concerns. In addition, soil action levels are presented for potential nuisance concerns (odors, general resource degradation, etc.), terrestrial ecological concerns (e.g., phytotoxicity) and potential emissions of vapors from contaminated soil to indoor air. Additional groundwater action levels are presented for potential nuisance concerns and the potential emission of vapors from contaminated groundwater to indoor air. This is discussed in detail in Chapter 2 and in Appendix 1.

1.3.1.2 Changes to Site Categories

Under the 1996 RBCA program, release sites are categorized into two groundwater utility scenarios – "Drinking Water Source Threatened" and Drinking Water Source NOT Threatened" (Figure 1). Groundwater utility is determined based on the location of the site with respect to the Underground Injection Control Line and the state *Aquifer Identification and Classification* technical reports prepared by the University of Hawai'i. This procedure is summarized in a policy update dated September 19, 1995. Sites were further categorized based on annual rainfall ($\leq$200cm/year and >200cm/year).

These categories are retained for use in this document but two additional categories are added – "Release Site $\leq$150m From a Surface Water Body" and "Release Site >150m From a Surface Water Body" (Figure 2). This is intended to enhance screening and monitoring of contaminated groundwater in close proximity to surface water bodies. Groundwater quality goals vary within each category, depending on the driving environmental concern for each specific contaminant. This is discussed in more detail below as well as in Chapter 2 and Appendix 1.

1.3.1.3 Updates to Groundwater Action Levels

Drinking water goals incorporated into the 1996 HIDOH RBCA document focused on toxicity to humans (e.g., Primary Maximum Contaminant Levels or MCLs). For many chemicals that are not carcinogens, however, drinking water goals based on taste and odor concerns (e.g., Secondary MCLs) are lower than goals based on toxicity. For example, the USEPA Primary MCL for xylenes is 10,000 ug/L. The USEPA Secondary MCL for xylenes is significantly lower, however, at 20 ug/L (see Table D-2 in Appendix 1). In this update, taste and odor goals are used as drinking water action levels if lower than goals based on toxicity. This does not necessarily require that groundwater that is a potential source of drinking water be aggressively cleaned up to the taste and odor goal, only that more scrutiny is warranted if the groundwater is within the near-term capture zone of a currently operating water supply well (see Chapter 3).

Groundwater action levels presented in the 1996 RBCA document also incorporated surface water goals for the protection of aquatic habitats. Most groundwater outside of geologically diked areas of the islands ultimately migrates to and discharges into streams, bays or other ocean. As stated above, one environmental goal is to ensure that groundwater with concentrations of contaminants that exceed chronic surface water goals does not discharge into a sensitive aquatic habitat. In the 1996 RBCA document, groundwater goals intended to address this concern were based on promulgated surface water standards. In retrospect, however, many of these standards are based on acute rather than chronic impacts to aquatic habitats. For example, the HIDOH freshwater surface standard for benzene is 1,800 ug/L, based on potential acute toxicity. The current USEPA chronic goal for benzene is, in contrast, only 46 ug/L. In addition, no surface water standards were available for some chemicals (e.g., xylenes).

In this update, chronic surface water goals for all chemicals listed in the lookup tables are compiled. For release sites and contaminated groundwater situated within 150m (approximately 500 feet) of a surface water bodies, the chronic goals, rather than acute goals, are incorporated into the lookup tables. Acute goals are retained for use in distal areas located more than 150m from a surface water body. This again does not necessarily imply that all groundwater situated within 500 feet of a surface water body must be aggressively remediated to chronic surface water goals, only that additional evaluation is warranted to ensure that environmental goals appropriate to that site are met. This is discussed further in Chapter 2 and 3 as well as Appendix 1.

1.3.1.4 Updates to Soil Action Levels

Soil direct-exposure action levels presented in the 1996 HIDOH document were developed using a model that allowed the actual thickness of the contaminated soil to be preset. This is an important variable in evaluating the maximum duration and magnitude of the emission of volatile chemicals from soil to outdoor air over time. A two-meter thickness of contaminated soil was assumed and considered to be adequately conservative for the majority of sites.

Direct-exposure action levels for soil presented in this document are based on an updated, "infinite source" model currently used by USEPA Region IX to develop the Preliminary Remediation Goals (PRGs). This model assumes an infinite thickness of contaminated soil. Action levels developed by this model are consequently up to an order of magnitude lower (more stringent) than those based on "finite source" models. Adjustment of direct-exposure action levels for soil to reflect the site-specific thickness of contaminated soil is a relatively simple process and can be done using a spreadsheet currently available from HIDOH (updated "DETIER2" spreadsheet, available from HIDOH).

The soil action levels for the protection of groundwater presented in the 1996 HIDOH document were developed based on detailed computer models, using the SESOIL leaching application. The models in general assumed 200cm of annual rainfall

(approximately 75cm of infiltrating surface water), a very permeable soil type that allowed leachate to quickly reach groundwater and a depth to groundwater of one meter.

Preparing and running detailed SESOIL models is a time consuming process. As an alternative, the leaching based soil action levels presented in this document are based on a simplified SESOIL algorithm based on similar site conditions (refer to Appendix 1). Use of the model only requires input of the target groundwater goal (e.g., the drinking water MCL) and two easily obtained constants for the chemical (Henry's Law constant and sorption coefficient or "koc"). This allows more rapid calculation of soil action levels for groundwater protection concerns. Action levels produced by the simplified algorithm are reasonable comparable to those produced by the full SESOIL model in the 1996 HIDOH document (e.g., compare action levels in Appendix F of the 1996 HIDOH document to Table E-1 in Appendix 1). Alternative action levels presented in Appendix F of the 1996 document for varying depth to groundwater can still be used on a site-by-site basis, as can action levels for higher rainfall areas.

1.3.1.5 Soil and Groundwater "Ceiling Levels"

"Ceiling Levels" or action levels for potential nuisance concerns (odors, sheens, general resource degradation, etc.) are also incorporated into the updated lookup tables. This primarily affects final action levels for contaminants that have relatively low toxicity to humans but are highly odiferous. Petroleum contaminants and phenols are examples. As noted in Tables A and B of this volume, nuisance-based ceiling levels for Total Petroleum Hydrocarbons could drive cleanup of soil exposed or potentially exposed at the ground surface in both residential and commercial/industrial areas. For residential sites with private yards, nuisance concerns should generally be addressed for soil situated within three meters (ten feet) of the ground surface. For other sites, nuisance concerns should be addressed by a minimum one-meter (three feet) cap of clean soil or by isolating the soil under pavement or a building foundation.

1.3.2 USEPA Region IX PRGs

The U.S. Environmental Protection Agency (USEPA) Region IX "Preliminary Remediation Goals" or "PRGs" are included in this document as soil action levels for direct-exposure concerns (USEPA 2002). Expansion of the USEPA PRGs in the lookup tables presented in this document includes:

- Addition of soil and groundwater action levels for indoor-air impact concerns;
- Addition of groundwater action levels for the protection of aquatic habitats/surface water quality;
- Use of a more rigorous leaching model to develop soil action levels for protection of groundwater quality;
- Addition of soil action levels for urban area, ecological concerns;
- Addition of soil and groundwater "ceiling levels" to address gross contamination and

general resource degradation concerns; and
- Addition of soil and groundwater action levels for Total Petroleum Hydrocarbons (TPH);
- Addition of direct-exposure action levels for construction and trench workers' exposure to subsurface soils (see Appendix 1).

Use of the USEPA Region IX PRGs is discussed further in Section 3.2 of Appendix 1. A copy of the PRG background document is provided in Appendix 2.

1.3.3 OSHA Standards Permissible Exposure Levels

The National Institute for Occupational Safety and Health (NIOSH) is the Federal agency responsible for conducting research and making recommendations for the prevention of work-related disease and injury, including exposure to hazardous chemicals in air (NIOSH 2003). NIOSH develops and periodically revises Recommended Exposure Limits (RELs) for hazardous substances in the workplace. The RELs are used to promulgate Permissible Exposure Levels (PELs) under the Occupational Safety and Health Act (OSHA).

OSHA Permissible Exposure Levels (PELs) for indoor air are intended for use in controlled, industrial work areas where generally healthy employees are aware of potential health hazards associated with the chemicals they are using and are trained to take proper precautions and minimize exposure (NIOSH 2003). OSHA PELs are **not** appropriate for use at commercial/industrial sites where the chemical is not currently being used. This includes sites affected by the migration of offsite releases (e.g., via emissions from a moving plume of contaminated groundwater). Indoor-air protection goals for these sites should be based on long-term (chronic) health risk to workers. Such risk-based goals levels are typically much more stringent than OSHA PELs.

For example, the current OSHA PEL for trichloroethylene (TCE) is 678,000 ug/m^3 (100 ppmv, NIOSH 2003). Comparable risk-based action levels for uncontrolled, commercial/industrial settings included in this document fall between 2.0 ug/m^3 and 10 ug/m^3 (carcinogenic effects vs noncarcinogenic effects, respectively; refer to Table C in this volume and Table C-3 in Appendix 1). The PEL is applicable to work areas where TCE is being used and the employees have been properly trained to minimize exposure. The risk-based goals are applicable to all other areas.

1.4 Chemicals Not Listed In Lookup Tables

The lookup tables in this document list 100-plus chemicals most commonly found at sites with impacted soil or groundwater, a significant increase over the approximately 26 chemicals listed in the 1996 document. Inclusion of EALs for additional chemicals is a relatively straightforward process, provided that adequate supporting data are available. To obtain EALs for chemicals not listed in the lookup tables, the interested party should

contact the HIDOH staff noted at the beginning of this document. Development of EALs will be carried out in the same manner as done for the listed chemicals. As an alternative, EALs may be developed by qualified persons and submitted to the overseeing regulatory agency for review (refer to Section 3.0).

1.5 Limitations

The Tier 1 EALs presented in the lookup tables are NOT required, regulatory "cleanup standards". This document is intended to serve as a supplement to cleanup standards currently presented in the Hawai'I Administrative Rules, Title 11, Chapter 281 (Underground Storage Tanks). Use of the EALs as actual cleanup levels should be evaluated in view of the overall site investigation results and the cost/benefit of performing a more detailed environmental risk assessment. The EALs are intended to be conservative for use at the vast majority of impacted sites in developed areas. As discussed in Chapter 3, however, use of the Environmental Action Levels may not be appropriate for final assessment of all sites. Examples include:

- Sites that have a high public profile and warrant a detailed, fully documented environmental risk assessment;
- Sites with high rainfall (>200cm/year) and subsequent high surface water infiltration rates (i.e., infiltration >720mm or 28 inches per year, refer to additional soil action levels in Table 2-1 in Chapter 2),
- Sites where inorganic chemicals (e.g., metals) are potentially mobile in leachate due to soil or groundwater conditions different than those assumed in development of the lookup tables (e.g., low pH at mine sites);
- Areas where impacts pose heightened threats to terrestrial ecological habitats (e.g., parklands, nature reserves, etc.); and
- Sites where more than three known or suspected carcinogens or more than five chemicals with similar noncarcinogenic health effects have been identified.
- Sites affected by tides, rivers, streams, etc. where there is a potential for erosion and concentration of contaminants in aquatic habitats.

Examples of other site characteristics that may warrant a more detailed environmental risk assessment are discussed in Chapter 3 (refer also to discussion of action levels in Appendix 1). In such cases, the information provided in this document may still be useful for identification of potential environmental concerns and development of strategies for preparation of a more site-specific risk assessment.

EALs for chemicals that are known to be highly biodegradable in the environment may in particular be overly conservative for use as final cleanup levels. For example, final soil EALs for Total Petroleum Hydrocarbon (TPH) and many noncarcinogenic, petroleum-related compounds (e.g., xylenes) are driven by the protection of groundwater quality. If long-term monitoring demonstrates that actual impacts to groundwater do not exceed action levels then soil action levels for leaching concerns can be omitted from consideration in a Tier 2 assessment.

Soil EALs do not consider potential water- or wind-related erosion and deposition of contaminants in a sensitive ecological habitat. This may especially be of concern for metals and pesticides that are only moderately toxic to humans but highly toxic to aquatic and terrestrial biota (e.g., copper).

It is conceivable that soil, groundwater and soil gas action levels for the emission of chlorinated, volatile organic compounds to indoor air concerns may not be adequately conservative in some cases. This is most likely to occur at sites where the vapor permeability of vadose-zone soils is exceptionally high (e.g., highly fractured bedrock, gravels, etc.) and/or where building designs, ventilation systems and local environmental conditions otherwise lead to higher-than-expected vapor flow rates through foundations (e.g., houses with heating systems in basements). As discussed in Appendix 1, conservative target risks are used in part to address these uncertainties.

2

Tier 1 Lookup Tables

2.1 Organization of Lookup Tables

Environmental Action Levels (EALs) are presented in two separate lookup tables and reflect four default site scenarios, based on groundwater utility and proximity to a surface water body (Figure 2). The first table presents soil and groundwater action levels for sites that directly overlie a current or potential source of drinking water (Table A). Two sets of action levels are provided, one for sites within 150m (500 feet) of a surface water body and one for sites located more than 150m (500 feet) from a surface water body. A second table presents a similar set of action levels for sites that do *not* directly overlie a current or potential source of drinking water (Table B).

The EALs in each table are intended to collectively addresses the environmental concerns noted below. For the purpose of this document, "soil" refers to any unlithified material in the vadose zone that is situated above the capillary fringe of the shallowest saturated unit.

Groundwater Quality:
- Protection of human health
  - Current or potential drinking water resource;
  - Emission of subsurface vapors to building interiors;
- Protection of aquatic habitats (discharges to surface water);
- Protection against nuisance concerns (odors, etc.) and general resource degradation.

Soil Quality:
- Protection of human health
  - Direct/indirect exposure to impacted soil (ingestion, dermal absorption, inhalation of vapors and dust in outdoor air);
  - Emission of subsurface vapors to building interiors;
- Protection of groundwater quality (leaching of chemicals from soil);
- Protection of terrestrial (nonhuman) habitats;
- Protection against nuisance concerns (odors, etc.) and general resource degradation.

Shallow Soil Gas:
- Protection of human health
  - Emission of subsurface vapors to building interiors.

A summary of environmental concerns considered in the EALs is depicted schematically in Figure 3. This is correlative to a "conceptual site model" that may be prepared for a detailed environmental risk assessment. For the purpose of the Tier 1 lookup tables, soils are assumed to be exposed or potentially exposed in a "residential" or sensitive land-use setting. This includes sites to be used for residences, hospitals, day-care centers and other sensitive purposes. Soil and groundwater EALs listed under this category incorporate conservative assumptions regarding long-term, frequent exposure of children and adults to impacted soils in a residential setting (see Section 3.2 in Appendices 1 and Appendix 2).

For each chemical listed in the lookup tables, action levels were selected to address each applicable environmental concern under the specified combination of site characteristics. The lowest of the individual action levels for each concern was selected for inclusion in the summary Tier EAL tables presented in Volume 1 of this document. This ensures that the EALs presented in these tables are protective of all potential environmental concerns and provides a tool for rapid screening of site data. The degree to which any given concern will "drive" environmental risk at a site depends on the actual potential for exposure and the toxicity and mobility of the chemical. Where EALs are exceeded, the detailed tables provided in Appendix 1 can be used to identify the specific environmental concerns that may be present at the site.

An example of the selection of summary, Tier 1 EALs for benzene is presented in Figure 2. In this example, groundwater immediately underlying the site is a source of drinking water. The site is to be used for residential purposes and is located within 150m of a surface water body. The final groundwater action level for benzene is driven by drinking water toxicity concerns (lowest GAL = 5.0 ug/L). The individual action levels can also be used to identify specific, potential environmental concerns at a site. Benzene in groundwater at a concentration of 50 ug/L, for example, would pose drinking water toxicity concerns (action level 5.0 ug/L) but not vapor intrusion concerns (action level 2,000 ug/L) and only marginal concerns regarding the discharge of contaminated groundwater into a body of surface water (action level 46 ug/L). The benzene would probably not produce taste or odor concerns in drinking water by at this level (action level 170 ug/L).

As noted in Figure 4, leaching and potential impacts to groundwater quality drive environmental concerns for benzene in soil under the assumed site scenario (lowest SAL = 0.22 mg/kg). Benzene in soil at a concentration of 1.0 mg/kg would pose marginal direct-exposure concerns (action level 0.59 mg/kg) and vapor intrusion concerns (action level 0.59 mg/kg). Odors from the soil would not pose nuisance concerns (action level 500 mg/kg) and the soil would not be particularly toxic to urban area flora or fauna (action level 25 mg/kg). In the absence of cleanup, soil gas sampling would be recommended to further evaluate vapor intrusion concerns. The correlative soil gas action level for residences is 350 ug/m^3. If this action level was exceeded, indoor air sampling may be required (indoor air action level 0.35 ug/m^3). Ambient levels of

benzene in outdoor air from auto exhaust (up to 5 ug/m^3 in some mainland areas) may hinder full evaluation of vapor intrusion concerns at sites with only moderate levels of contamination, however. A more detailed discussion of the action levels provided in Appendix 1.

2.2 Use of Lookup Tables

2.2.1 Steps To Use Of Tables

A step-by-step use of the lookup tables is summarized below and discussed in more detail in the following sections. An outline and discussion of information that should be included in a Tier 1 environmental risk assessment is provided in Section 2.9.

Step 1 - EAL Updates and Applicability
Check with the overseeing regulatory agency to determine if the EALs can be applied to the subject site. Ensure that the most up-to-date version of this document is being used.

Step 2: Identify All Chemicals of Potential Concern
An environmental risk assessment must be based on the results of a thorough site investigation, where all chemicals of potential concern have been identified. A summary of the site investigation results should be included in the risk assessment in order for it to be reviewed as a "stand alone" document. A general outline of site investigation information that should be included in a Tier 1 risk assessment is provided in Section 2.9.

Step 3: Select Lookup Table(s)
Determine the beneficial use of impacted or threatened groundwater beneath the site and the distance to the nearest surfaced water body from the downgradient edge of the release site (refer to Figure 2). In general, all groundwater inland of the Underground Injection Control (UIC) lines should initially be treated as a current or potential source of drinking water (see Section 2.3 and discussion in 1996 HIDOH RBCA document). Reference can be made to the Water Resources Research Center *Aquifer Identification and Classification* reports, however, to evaluate the utility of the groundwater on a more site-specific basis. This information is then used to select soil and groundwater action levels in Table A (potential source of drinking water) or Table B (not a potential source of drinking water).

Steps 4: Select Soil and/or Groundwater EALs
Select appropriate soil EALs from the appropriate lookup table. EALs for groundwater are provided in the adjacent column of each table and are not dependent on land use or depth to impacted soil. Replace EALs with naturally occurring, background concentrations of chemicals of concern (e.g., arsenic) or laboratory method reporting levels if higher (see Section 2.6). For areas of high rainfall (>200cm/year), additional

soil action levels for elevated leaching concerns should also be considered (refer to Table 2-1 in Chapter 2).

Step 5: Determine Extent of Impacted Soil and/or Groundwater

Using the selected EALs, determine the extent of impacted soil or groundwater and areas of potential environmental concern at the site and offsite, as required. (Soil data should be reported on a dry-weight basis (see Appendix 1, Section 6.2). This does not significantly affect reported sample data but is more in line with assumptions used in the models.) If a groundwater plume originating from an inland release site is suspected to have migrated to within 150m of a surface water body, then additional downgradient investigation may be necessary, using more conservative action levels for this zone.

Steps 6: Evaluate The Need For Additional Investigation or Corrective Actions; Submit Appropriate Reports

Based on a comparison of available site data to the EALs, evaluate the need for additional action at the site (e.g. additional site investigation, remedial action, preparation of a more site-specific risk assessment, etc.). For sites where sample data are limited, it will be most appropriate to compare the maximum-detected concentrations of chemicals of concern to the EALs to initially evaluate potential environmental concerns.

For sites where an adequate number of data points are available, the use of statistical methods to estimate more site-specific exposure point concentrations and evaluate environmental risks may be appropriate. The exposure point concentration is generally selected as the lesser of the maximum-detected concentration and the 95% upper confidence interval of the arithmetic mean of sample data. Guidance for the estimation of exposure point concentrations, use of "non-detect" data, and other issues is provided in the California EPA documents *Preliminary Endangerment Assessment Guidance Manual* (CalEPA 1994b) and *Supplemental Guidance For Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities* (CalEPA 1996a), among other sources. As discussed in these documents, sample data collected outside of impacted areas should generally not be included in estimation of exposure point concentrations. **For residential land use scenarios, sample data should be collected on a close grid spacing (e.g., 10m/30ft spacing) and not be averaged over areas greater than typical backyards (e.g., 100m^2/1,000 ft^2, CalEPA 1996a).**

This evaluation should be summarized in the Tier 1 Environmental Risk Assessment report and workplans for additional corrective actions as needed (see Section 2.9). Decisions for or against additional actions should always be made in conjunction with guidance from the Department of Health. Adjustment of Tier 1 action levels under more site-specific, Tier 2 or Tier 3 assessments is discussed in Chapter 3.

2.2.2 TPH And Related Compounds

Impacts to soil and water from petroleum mixtures are evaluated in terms of both Total Petroleum Hydrocarbon (TPH) and target "indicator chemicals" for the given petroleum mixture. Indicator chemicals typically recommended for petroleum mixtures include (after CalEPA 1996a):

Monocyclic Aromatic Compounds (primarily gasolines and middle distillates):

- benzene
- ethylbenzene
- toluene
- xylene

Fuel additives (primarily gasolines):

- MTBE
- other oxygenates as necessary

Polycyclic Aromatic Compounds (primarily middle distillates and residual fuels):

- acenaphthene
- acenaphthylene
- anthracene
- benzo(a)anthracene
- benzo(b)fluoranthene
- benzo(g,h,i)perylene
- benzo(a)pyrene
- benzo(k)fluoranthene
- chrysene
- dibenzo(a,h)anthracene
- fluoranthene
- fluorene
- indeno(1,2,3)pyrene
- methylnaphthalene (1- and 2-)
- naphthalene
- phenanthrene
- pyrene

The TPH EALs should be used in conjunction with EALs for these chemicals. As discussed in Appendix 1, the "middle distillates" category of TPH includes diesel fuel kerosene, stoddard solvent, home heating fuel, jet fuel and similar petroleum mixtures. "Residual fuels" includes heavy petroleum products such as No. 6 fuel oil ("Bunker C"), lubricating oils, "waste oils" and asphalts. Soil and groundwater impacted by releases of waste oil may also require testing for heavy metals and chemicals such as chlorinated solvents and PCBs. Action levels for these chemicals are included in the lookup tables. A more detailed discussion of action levels for petroleum and petroleum-related compounds is provided in Appendix 1.

2.2.3 Areas of High Rainfall (>200cm/year)

Soil screening presented in Tables A and B are based on an assumption that annual rainfall at the site is less than 200cm (approximately 80 inches). This was used to develop soil action levels for leaching concerns and protection of groundwater quality. For sites located in areas of significantly higher rainfall, more stringent soil screening levels for leaching concerns are appropriate. This is especially important for sites contaminated with chlorinated solvents or other highly mobile compounds that are not significantly biodegradable.

Additional screening levels for common contaminants in soil that are highly leachable are provided in Table 2-1. These screening levels were taken from the 1996 HIDOH RBCA document and adjusted to reflect updated groundwater action levels. For sites where the annual rainfall exceeds 200cm/year, these screening levels should be used in conjunction with soil screening levels in Tables A and B. Additional guidance on the development of more site-specific soil action levels for leaching concerns is provided in Chapter 3 and Appendices 1 and 5.

2.3 Groundwater Utility

Groundwater utility is determined based on the location of the site with respect to the Underground Injection Control (UIC) Line and the state *Aquifer Identification and Classification* technical reports prepared by the University of Hawai'i. This procedure is summarized in a policy update dated September 19, 1995 (see Appendix 8). In general, groundwater situated mauka (inland) of the UIC line is considered a potential source of drinking water, provided it is present in a suitably productive geologic formation. Groundwater situated makai (oceanward) of the UIC line is generally considered to not be a potential source of drinking water, due to high salinity, low permeability and production and/or historic contamination.

In general, soil and groundwater action levels are more stringent for sites that threaten a potential source of drinking water (e.g., compare Tables A and B). This is particularly true for chemicals that are highly mobile in the subsurface and easily leached from impacted soil. For chemicals that are especially toxic to aquatic life (e.g., several long-chain hydrocarbons, pesticides and heavy metals), however, action levels for sites that threaten drinking water resources may be driven by surface water/aquatic habitat protection concerns. This is discussed in more detail in the following section.

2.4 Threat To Surface Water Habitats

For the purposes of the Tier 1 lookup tables, it is assumed that impacted or potentially impacted groundwater at all sites could at some time migrate offsite and discharge into a body of surface water. This could occur due to the natural, downgradient migration of

groundwater or to human activities such as dewatering of construction sites. To address this concern, groundwater action levels for both drinking water sources (Table A) and non-drinking water sources (Table B) include consideration of surface water goals (see Chapter 2 of Appendix 1).

For sites located more than 150m from a surface water body, acute surface water goals were considered in development of groundwater action levels. This follows the approach used in the 1996 RBCA document (refer to Section 1.3). Based on studies of petroleum-contaminated groundwater, natural degradation processes significantly reduced the likelihood that these types of plumes will extend more than one- or two-hundred meters from the original release area. An argument could be made that plumes located more than a few hundred meters will never naturally migrate to a surface water body and therefore this concern does not need to be addressed. Screening and monitoring of these plumes with respect to acute surface water goals will, however, assist in avoiding the unanticipated migration and discharge of a plume into shoreline areas or unmonitored extraction and discharge of the plume during construction or utility maintenance related activities. This is especially important for contaminants that do not readily biodegrade, such as chlorinated solvents and MTBE. Additional characterization and monitoring of groundwater impacted with these contaminants may be needed if it is suspected that the plumes could move to within 150m of a surface water body at levels above chronic surface water goals.

Ideally, concentrations if contaminants in groundwater should meet chronic surface water goals at the point that the groundwater discharges into a sensitive aquatic habitat. For sites located within 150m of a surface water body, more stringent chronic goals were therefore considered in development of groundwater screening levels (zones A-2 and B-2 in Figure 2). This is likely to be overly conservative for many sites but is appropriate under a Tier 1 assessment. If long-term monitoring of groundwater (e.g., two-plus years) adequately demonstrates that a plume if not likely to discharge into a surface water body above chronic goals even though it is within 150m of the body, then the use of acute surface water goals as final cleanup and closure levels may be appropriate (similar to the 1996 RBCA document). This is discussed in more detail in Chapter 3 under Tier 2 environmental risk assessments.

The groundwater action levels for potential impacts to aquatic habitats do not consider dilution of groundwater upon discharge to a body of surface water. Benthic flora and fauna communities situated below or at the groundwater/surface water interface are assumed to be exposed to the full concentration of chemicals in impacted groundwater. Use of a generic "dilution factor" to adjust the surface water protection action levels with respect to dilution of groundwater upon discharge to surface water was therefore not considered. Consideration of dilution/attenuation factor and alternative groundwater action levels for the protection of surface water quality may, however, be appropriate on a limited basis.

The soil and groundwater action levels presented in the lookup tables do not directly address the protection of sediment quality. Site-specific concerns could include the accumulation and magnification of concentrations of highly sorptive chemicals in sediment over time due to long-term discharges of impacted groundwater. This may be especially true for groundwater impacted with highly sorptive (lipophyllic) chemicals, including heavy petroleum products.

Potential erosion and runoff of surface soils from impacted sites may also need to be considered, particularly at sites impacted with metals and pesticides that are situated near a sensitive body of surface water. The need for a more detailed, ecological risk assessment of impacts to sediment should be evaluated on a site-by-site basis and discussed with the Department of Health.

2.5 Screening For Indoor-Air Impact Concerns

Volatile chemicals can be emitted from contaminated soil or groundwater and intrude overlying buildings, impacting the quality of indoor air. Heating systems, basements, and strong winds can exacerbate this problem by reducing the internal air pressure and creating a "vacuum effect" that enhances the advective flow of vapors out of the underlying soil and into the building. Additional information on subsurface vapor intrusion into buildings is provided in the USEPA document *User's Guide For The Johnson and Ettinger (1991) Model For Subsurface Vapor Intrusion Into Buildings* (USEPA 2000; refer also to Appendix 1).

The direct collection and analysis of indoor air samples would seem to be an easy way to evaluate this concern. Identification of the source of impacts is complicated, however, by the presence of the same chemicals in many household goods (aerosol sprays, dry-cleaned clothing, cleaners, etc.). In addition, plumes of groundwater impacted with volatile chemicals are known to extend over significant areas and comprehensive testing of every structure over the plume is not practical.

As an alternative, the comparison of site groundwater, soil gas and soil data to conservative action levels for indoor air concerns is recommended. Action levels incorporated into this document are based on scientific models for vapor intrusion into buildings as well as a growing body of data from actual field investigations. A detailed discussion of the action levels is presented in Appendix 1. The following three-phase, sequential approach is recommended for initial evaluation of potential indoor-air impact concerns at sites where shallow groundwater has been impacted by volatile chemicals:

1) Compare groundwater data to appropriate action levels for indoor air concerns (see Table C-1a of Appendix 1).

2) For areas over the plume where groundwater action levels for indoor-air concerns are approached or exceeded (e.g., >2,000 ug/L benzene), collect shallow soil gas samples under (preferred) or adjacent to buildings and compare results to soil-gas action levels for this concern (see Table C).

3) At sites where soil-gas action levels for indoor-air concerns are approached or exceeded (e.g., >310 ug/m^3 benzene), collect indoor-air samples and compare results to indoor-air action levels (e.g., 0.31 ug/m^3 benzene, see Table C).

For sites where the vapor permeability of shallow soils has not been evaluated, action levels for groundwater overlain by highly permeable vadose-zone soils should be used. Imported fill material or disturbed native soils should be considered to be highly permeable unless site-specific data indicates otherwise.

Unless inhibited by very high water tables or other obstacles, soil gas samples should be collected immediately beneath the foundations of existing buildings (e.g., "subslab" or in crawl spaces) or three to five feet below ground surface in open areas where buildings may be constructed in the future. Soil gas samples collected from depths less than three feet are currently considered unreliable due to the increased potential to draw in ambient, surface air. If site-specific modeling of vapor flow rates or indoor-air impacts is to be carried out, the collection of additional geotechnical data at the time soil gas samples are collected should be considered (soil grain-size analysis, moisture content, vapor permeability, etc.).

Soil action levels for potential indoor-air concerns are incorporated into the summary tables of this volume and presented separately in Table C-1b of Appendix 1. At sites where minor releases of volatile chemicals have occurred (e.g., restricted spills around underground tank fill ports), direct comparison of soil action levels to site data is generally acceptable. If action levels are exceeded, a similar approach to that outlined above for impacted groundwater is recommended. The restricted size of soil samples and the difficulty in predicting vapor-phase concentrations of chemicals from soil data limits the use of this data as a stand-alone tool for evaluating indoor-air concerns. **At sites where significant releases of volatile chemicals have occurred, soil gas samples should be collected and used to evaluate vapor intrusion concerns.**

Guidance on the collection of indoor air and soil gas samples is provided in the following documents, among other sources:

- *Indoor Air Sampling And Evaluation Guide* (2002): Massachusetts Department of Environmental Protection, Office of Research and Standards, WSC Policy #02-430; http://www.state.ma.us/dep/bwsc/finalpol.htm;

- *Soil Gas Advisory* (January 2003): Department of Toxic Substances Control and Los Angeles Regional Water Quality Control Board; http://www.dtsc.ca.gov/PolicyAndProcedures/SiteCleanup/SMBR_ADV_activesoilgasinvst.pdf.

Additional information on the intrusion of subsurface vapors into buildings will be incorporated into this document as available. Individuals are encouraged to provide comments and suggestions to the contacts listed in the front of this document at anytime.

2.6 Substitution of Laboratory Reporting Limits and Ambient Background Concentrations for EALs

In cases where an EAL for a specific chemical is less than the laboratory method reporting limit for that chemical (as agreed upon by the Department of Health), it is generally acceptable to consider the method reporting limit in place of the screening level. Potential examples include the action levels for dioxin and some pesticides in soil and groundwater and action levels for carcinogenic volatile chemicals in indoor-air.

Background concentrations of metals in soils should be used as soil and groundwater action levels in cases where they exceed risk-based action levels for human health and environmental concerns presented in this document. This is particularly an issue for arsenic, chromium and even lead in some soils in Hawai'i. For example, background concentrations of arsenic in soils typically fall between 5 mg/kg to 12 mg/kg and can range up to 20 mg/kg. This is well above the health-based, direct-exposure goals for arsenic in soil of 0.39 mg/kg for residential exposure and 1.6 mg/kg for commercial/industrial exposure (Appendix 1, Tables I-1 and I-2).

Based on professional judgment and for provisional use in this document, background concentrations of arsenic and total chromium in soils in Hawai'i are assumed to be 20 mg/kg and 500 mg/kg, respectively (refer to Appendix 1, Tables A and B). Unless a release of these chemicals is known to have occurred at a site, further investigation of soil with concentrations of arsenic and total chromium below these levels is not generally necessary. Additional review of background total concentrations of these metals in soil should be carried out at sites where the default values are exceeded. If reported levels of total chromium still appear to exceed anticipated site-specific background levels, then soil samples should be tested for Cr VI and Cr III. Data should be compared to action levels for these specific species of chromium and action taken as needed.

2.7 Implied Land-Use Restrictions Under Tier 1

Allowing the option to tie action levels or cleanup levels to site-specific land use and exposure conditions can save considerably in investigation and remediation costs. For example, the screening level for polychlorinated biphenyls (PCBs) in surface soils is 1.1

mg/kg in residential areas but up to 11 mg/kg for commercial/industrial areas (Appendix 1, Tables I-1 and I-2). Even higher levels of PCBs could potentially be allowed to remain in place onsite provided that adequate controls to mitigate potential exposure are put into effect (e.g., permanent cap, protection of groundwater, etc.).

The use of final cleanup levels less stringent than those appropriate for residential/unrestricted land use will, however, place restrictions on future use of the property. For example, if a site is remediated using EALs (or alternative criteria) intended for commercial/industrial land use then the site cannot be used for residential purposes in the future without additional evaluation. In most cases, this will require that a formal covenant to the deed be recorded to restrict future use of the property.

Development of site-specific cleanup levels for screening level deep soils at a site similarly assumes that the impacted soil will remain isolated below the ground surface "for eternity". For single-family, residential areas, future disturbance of soil situated greater than three meters is generally considered to be unlikely (CalEPA 1996a) and use of alternative EALs for soil below this depth without restrictions may be reasonable (see Section 3.2). During the redevelopment of properties for commercial/industrial or high-density residential use, however, excavation and removal of soils from depths in excess of five or even ten meters could take place (e.g., for underground parking garages, elevator shafts, utilities, etc.). The need to impose enforceable, institutional controls for proper management of deep, impacted soils at properties where the subsurface EALs (or alternative cleanup levels) are applied should be discussed with the HIDOH on a site-by-site basis.

Land-use restrictions inherent in the selection of EALs from the Tier 1 lookup tables (or assumptions used in site-specific risk assessments) should be kept as minimal as possible. **Cleanup of a site to residential goals should always be considered, even if the property will be used for commercial/industrial purposes for the foreseeable future.** Even if the property is ultimately only cleaned up to meet industrial/commercial goals, this will allow the property owner to understand the effort and cost to remediate the site to residential/unrestricted land use purposes in the future. If the soils in fact meet EALs for unrestricted land use after cleanup then this should be clearly stated in the site closure report. Recognizing this point may prove important should the site unexpectedly become desirable for other, more sensitive uses. **Assumptions that impacted soil at a property will remain isolated at shallow depths under pavement, buildings or some other type of "cap" should likewise be avoided if at all possible.** It is preferable that soils that are to be left in place under caps be remediated to meet direct-exposure action levels for construction workers at a minimum (refer to Appendix 1, Table I-3).

If a site is not cleaned up to meet residential land-use goals, appropriate covenants to the property deed should be prepared and methods to prevent or manage future disturbance of the soil should be clearly described and ensured. A foresighted approach in the use of Tier 1 EALs or alternative, site-specific cleanup levels will allow more flexibility in

future use of a site, help avoid unexpected complications during site redevelopment and minimize the liability of future land owners.

2.8 Cumulative Risks at Sites With Multiple Chemicals of Concern

Risks posed by direct exposure to multiple chemicals with similar health affects are considered to be additive or "cumulative." For example, the total risk of cancer posed by the presence of two carcinogenic chemicals in soil is the sum of the risk posed by each individual chemical. The same is true for chemicals that cause noncarcingenic health effects. A summary of example target health effects for the chemicals listed in the lookup tables is provided in Appendix 1 (Table J).

Use of EALs for single chemicals is limited to the extent that the action levels remain protective of human health should other chemicals with similar health effects also be present. Soil EALs are considered to be adequate for use at sites where no more three carcinogenic chemicals are present and the total risk posed by residual concentrations of chemicals with similar noncarcinogenic ("systemic") health effects does not exceed a target Hazard Index of 1.0. This is based on a combination of conservative exposure assumptions and target risk factors in direct-exposure models. Site-specific adjustment of action levels for human health concerns my need to be carried out where these conditions are not met. Refer to Appendix 1, Section 1.3, for additional discussion of this subject and in the documentation for USEPA Region IX Preliminary Remediation Goals provided in Appendix 2.

2.9 Framework For a Tier 1 Environmental Risk Assessment

Tier 1 environmental risk assessments should serve as "stand alone" documents that provide a good summary of environment impacts at a site and assess the threats posed to human health and the environment by these impacts. The risk assessment can be prepared as a component of a site investigation or remedial action report or as a separate document. Information on each of the topics listed below should be addressed in a report that presents the risk assessment (after MADEP 1995). Together, this information is intended to provide a basic "conceptual model" of site conditions. The level of detail required for each topic will vary depending on site-specific considerations.

1. Summarize Past, Current and Anticipated Future Site Activities and Uses:
   - Describe past and current site uses and activities;
   - Describe foreseeable future site uses and activities. **(Always include a comparison of site data to EALs for residential land use to evaluate need for formal covenants to the deed; see Section 2.7).**

2. Summary of Site Investigation:

- Identify all types of impacted media;
- Identify all sources of chemical releases;
- Identify all chemicals of concern;
- Identify magnitude and extent of impacts that exceed EALs to extent feasible and applicable (include maps of site with isoconcentration contours for soil and groundwater);
- Identify nearby groundwater extraction wells, bodies of surface water and other potentially sensitive ecological habitats;
- Ensure data are representative of site conditions.

3. Summarize Appropriateness of Use of Tier 1 Lookup Tables and EALs (see Section 1.5):
   - Do Tier 1 EALs exist for all chemicals of concern?
   - Does the site have a high public profile and warrant a fully documented, detailed environmental risk assessment?
   - Do soil and groundwater conditions at the site differ significantly from those assumed in development of the lookup tables (e.g., low pH at mine sites)?
   - Do impacts pose a heightened threat to sensitive ecological habitats (e.g., presence of endangered or protected species)?
   - Have more than three carcinogens or five chemicals with similar noncarcinogenic health effects been identified (see Section 2.8)?
   - Other issues as applicable to the site.
4. Groundwater Categorization (see Sections 2.3):
   - State the default utility use of impacted or potentially impacted groundwater beneath the site as determined by proximity to the UIC line and Aquifer Identification and Classification reports for that area; discuss the actual, likely beneficial use of groundwater based on measured or assumed quality of the groundwater and the hydrogeologic nature of the soil or bedrock containing the groundwater.
5. Exposure Point Concentrations (see Section 2.2, Step 6):
   - Identify maximum concentrations of chemicals present in impacted media.
   - Describe how alternative exposure point concentrations were determined (e.g., 95% UCLs), if proposed, and provide supporting data. **For residential land use scenarios, sample data should typically not be averaged over an area greater than 100m^2 (1,000 ft^2, presumed minimal size of an open backyard).**
   - Discuss the need to evaluate groundwater data with respect to surface water standards for potential bioaccumulation of chemicals in aquatic organisms, based on the size of the plume, the proximity of the plume to a body of surface water and the potential for minimal dilution of groundwater upon discharge to surface water (see Section 2.4).
   - Discuss how background concentrations of chemicals were determined, if considered for use in the risk assessment (see Section 2.6).

6. Selection of Tier 1 EALs and Comparison to Site Data (see Section 2.2)

- Summarize how Tier 1 EALs were selected with respect to the information provided above and additional assumptions as applicable.
- Compare site data to the selected summary Tier 1 EALs (presented in Volume 1) and discuss general results.
- If desired or recommended, compare site data to detailed EALs for individual environmental concerns (presented in Volume 2, Appendix 1) and discuss specific, potential environmental concerns present at site.

7. Conclusions:

- Describe the extent of soil and groundwater impacts above Tier 1 EALs, using maps and cross sections as necessary.
- Discuss if a condition of potential risk to human health and the environment exists at the site.
- Discuss if a more site-specific risk assessment is warranted at the site.
- Present a summary of recommended future actions proposed to address environmental concerns ay the site.
- Discuss the need to impose land-use restrictions and institutional controls at the site based on the results of the Tier 1 assessment (see Section 2.7; e.g., requirements for caps, etc.; need for covenant to deed to restrict land use to commercial/industrial purposes only, etc).

The above list is not intended to be exhaustive or representative of an exact outline required for all Tier 1 risk assessments. Requirements for completion of an adequate site investigation and Tier 1 environmental risk assessment should be discussed with the overseeing regulatory agency.

Table 2-1. Additional Soil Action Levels for Areas of High Rainfall (>200 cm/year).

	Soil Leaching Action Levels			
	Drinking Water IS Threatened		Drinking Water NOT Threatened	
CONTAMINANT	A-1 (Surface Water Within 150m) (mg/kg)	A-2 (Surface Water NOT Within 150m) (mg/kg)	B-1 (Surface Water Within 150m) (mg/kg)	B-2 (Surface Water NOT Within 150m) (mg/kg)
BENZENE	2.0E-03	2.0E-03	1.8E-02	6.8E-01
ETHYLBENZENE	2.8E-02	2.8E-02	2.7E-01	2.8E-01
TOLUENE	1.0E-01	1.0E-01	3.4E-01	1.0E+00
XYLENES	2.0E-03	2.0E-03	1.0E-02	2.0E-01
CARBON TETRACHLORIDE	2.4E-02	2.4E-02	4.7E-02	1.3E-01
CHLOROBENZENE	1.3E-02	2.5E-02	1.3E-02	8.0E-02
CHLOROFORM	6.3E-02	6.3E-02	3.9E-01	1.5E+00
METHYLENE CHLORIDE	2.4E-03	2.4E-03	1.2E+00	2.9E+00
TETRACHLOROETHYLENE	4.0E-02	4.0E-02	8.7E-01	8.7E-01
TRICHLOROETHANE, 1,1,1-	1.0E-02	3.3E-02	1.0E-02	1.0E+00
TRICHLOROETHYLENE	7.1E-03	7.1E-03	1.4E-01	1.4E-01

Notes:
Reference: Table E-2 in Appendix 1. Based on greater potential for groundwater impacts due to increased leaching of contaminants from soil.
Soil leaching action levels only generated for common, mobile contaminants modeled in 1996 HIDOH RBCA document.

3

Tier 2 and 3 Environmental Risk Assessments

3.1 Conditions Warranting More Detailed Risk Assessments

Use of the Tier 1 Environmental Action Levels is optional and independent environmental risk assessments may be undertaken for any site. In some cases, site conditions may negate the full use of the Tier 1 EALs and require preparation of a Tier 2 or Tier 3 risk assessment. Examples of site conditions that may warrant a more site-specific assessment of environmental concerns include (see also Section 1.5):

- Sites with groundwater contaminated above chronic surface water goals within 150m of a surface water body but unlikely to migrate to and discharge into that body at those concentrations.
- Sites with groundwater contaminated above taste and odor goals that is technically a source of drinking water but is not likely to impact an existing water supply well or a well that could be located in the area in the near future.
- Sites where alternative target risk levels or chemical-specific toxicity factors may be acceptable to the regulatory agency (see Appendix 1, Sections 1.3 and 3.2);
- Sites where the thickness of vadose-zone soils impacted by volatile organic compounds is greater than three meters (soil action levels for potential indoor air concerns may not be adequately conservative; see Appendix 1, Section 3.3);
- Sites where action levels for soil are driven by potential leaching concerns and groundwater data are available for evaluating actual groundwater impacts (main mass of impacted soil should be in contact with groundwater; see Appendix 1, Section 3.4);
- Sites where inorganic chemicals (e.g., metals) cannot be assumed to be immobile in soil (potential threat to groundwater quality; see Appendix 1, Section 3.4);

- Sites with soils impacted by pesticides, where final action levels are driven by leaching concerns and potential impacts to aquatic habitats but the site is not located near a body of surface water (e.g., dieldrin, endrin, endosulfan, etc.);

- Sites where the depth to groundwater is greater than ten meters below the base of impacted soil (soil action levels for leaching concerns may be excessively conservative; see Appendix 1, Section 3.4, and Appendix F in 1996 HIDOH RBCA document);

- Sites where protected terrestrial habitats or other ecologically sensitive areas are threatened (soil EALs may not be adequately conservative; see Appendix 1, Section 3.5);

- Sites where engineered controls will be implemented to eliminate or reduce specific exposure pathways (avoid whenever possible; see Section 2.7);

- Sites where the future erosion of shallow soils could lead to significant transport and concentration of contaminated sediments in sensitive ecological habitats; and

- Sites where field observations or site conditions otherwise indicate that the EALs may not be adequately conservative or may be excessively conservative.

The need for a detailed ecological risk assessment should be evaluated on a site-by-site basis for areas where these concerns may be present (see Section 3.3.5). Evaluation of landfills and sites impacted by highly acidic or basic wastes may in particular require the preparation of a detailed, site-specific assessment of groundwater and surface water impact concerns due to the possible elevated mobility of metals and other chemicals or the emission of potentially explosive vapors (e.g., methane). Soil leaching models incorporated into the Tier 1 EALs assume typical, ambient physio-chemical conditions in soil and groundwater (e.g., soil pH 5.0 to 9.0) and the relatively immobility of heavy metals and organic chemicals with very high sorption factors (e.g., PCBs, PAHs, stc.). This assumption may not hold true at sites where physiochemical conditions could lead to substantial mobility of these compounds. More rigorous field and laboratory studies may be required to adequately assess risks to human health and the environment in these cases.

Site-specific soil leaching action levels can be developed using SESOIL or an alternative model or approach. Steps used to develop the SESOIL-based action levels in the 1996 HIDOH RBCA document and considerations for site-specific action levels are provided in Appendix 5.

Final surface water and groundwater action levels for several pesticides that are highly toxic to aquatic organisms are very stringent (e.g., dieldrin, endrin, endosulfan, etc.; refer to Tables A and B in this volume and Table D series in Appendix 1). Correlative soil action levels for leaching concerns are likewise very low and potentially below widespread, ambient levels of these pesticides in soil (refer to Table A and B series in Appendix 1). The pesticides in question are only moderately mobile in the environment,

however, and the groundwater action levels and leaching based soil action levels are likely to be excessively conservative for sites not located beside or near a body of surface water. The need to apply the action levels to soil and groundwater data should be evaluated on a site-by-site basis. Less conservative action based only on human-toxicity, direct-exposure concerns may be appropriate at many sites.

Site-specific risk assessments are grouped under the loosely defined terms "Tier 2" and "Tier 3". The nature of these risk assessments is briefly discussed below.

3.2 Tier 2 Environmental Risk Assessments

3.2.1 Purpose

This process is intended to be a screening level risk assessment. There are limitations to the data gathered and collated for the environmental action levels presented under Tier 1. For example, the ecological action levels presented in the lookup tables are summarized to include sometimes very conservative data without identifying the receptor species and the endpoint and the original citation is not provided. While these limitations are inherent when compiling data of this sort, even with their limitations, the effort is considered worthwhile and even necessary. Further refinement of the environmental assessment must be pursued with the collection of site-specific data or further testing to show that the site-specific exposure and/or toxicity is a more realistic estimate of the overall risk. Tier 2 (and subsequently Tier 3) efforts are directed at confirming the estimates to move the screening risk assessment closer to a more realistic evaluation of risk by using more relevant site-specific data.

Tier 2 environmental risk assessments are intended to be relatively easy and cost-effective to prepare. Preparation of Tier 2 risk assessments will require a thorough understanding of the Tier 1 EALs being re-evaluated, however. Under Tier 2, specific Tier 1 action levels are adjusted or deleted to more closely reflect site conditions or alternative risk assumptions. Replacing only targeted components of the Tier 1 EALs reduces the need to prepare and justify an independent, detailed risk assessment when Tier 1 EALs cannot or should not be fully applied. This greatly reduces the time and cost incurred by both the regulated business and the overseeing regulatory agency in finalizing the risk assessment.

For example, the Tier 1 screening level for leaching concerns may not need to be considered at sites where groundwater monitoring data indicate that leaching impacts from soil to groundwater are minimal or not posing an adverse risk. A common modification under Tier 2 may also include the adjustment of target risk level for carcinogens in soils at commercial/industrial sites from 10^{-6} to a cumulative risk of 10^{-5} or a cumulative hazard index of 1.0 (and likely preparation of a covenant to the deed that formally restricts land use). This could increase the direct-exposure action levels for

carcinogens by a factor of up to ten. In these examples, all other components of the Tier 1 EALs are retained for use in the risk assessment. The modifications to Tier 1 assumptions are described and justified in the text of the report and the revised set of action levels are presented.

3.2.2 Example Tier 2 Modifications of Tier 1 EALs

A more detailed list of potential Tier 2 modifications to Tier 1 action levels is presented below (refer also to Appendix 1). These examples are not intended to reflect the full range of modifications possible:

Groundwater Action Levels

Drinking Water:

- Use of toxicity-based drinking water goals only (even if higher than taste and odor goals, e.g., xylenes) for cleanup and closure of groundwater that is classified as a drinking water source but is unlikely to be used as such in the foreseeable future.

- Exclusion of drinking water impact concerns based on natural groundwater quality or geologic characteristics of groundwater containing unit (e.g., brackish groundwater in coastal areas);

Indoor Air Impacts:

- Use of site-specific data for model input parameters (depth to groundwater, soil properties, building characteristics, target risk or hazard index, etc.);
- Use of soil gas and/or indoor air data to more directly evaluate potential impacts;
- Use of alternative chemical toxicity factors or target risk levels;

Surface Water Impacts:

- Use of acute surface water goals for final cleanup and closure of contaminated groundwater that is within 150m of a surface water body but, based on long-term monitoring and the nature of the contaminant, is unlikely to discharge into the surface water body at concentrations above chronic surface water goals;
- Exclusive use of freshwater or saltwater action levels;
- Consideration of alternative surface water action levels;

- Consideration of groundwater monitoring data and observed plume migration over time;
- Consideration of site-specific dilution effects during potential discharge of groundwater to surface water (generally not recommended except in highly developed and disturbed water front properties);

Gross Contamination:

- Use of alternative ceiling levels and/or site-specific observations and considerations regarding gross contamination concerns;

General:

- Consideration of method reporting limits or natural background concentrations of a chemical in place of the EAL.

Adjustment of Tier 1 groundwater action levels for drinking water and surface water protection is likely to be common on a site-by-site basis. Tier 1 actions levels in Table A incorporate the lowest of toxicity-based goals and goals for taste and odor concerns for groundwater that is a source of drinking water. Taste and odor goals for noncarcinogens are typically lower or more stringent than toxicity-based goals. For example, the toxicity-based drinking water goal for ethylbenzene is 700 ug/L but the goal for taste and odors is 30 ug/L. Both toxicity-based goals and taste and odors goals should be met in groundwater that is within 500m of active drinking water supply well screened in same aquifer or otherwise likely to be drawn into a supply well in the near future. **For sites that do not directly threaten an active water supply well, groundwater should be remediated to meet toxicity-based drinking water goals at a minimum before closure (refer to Table D-2 in Appendix 1).** This will allow more flexibility for cleanup of groundwater impacted by noncarcinogenic chemicals and is similar to guidance in the 1996 HODOH RBCA document. This should be supported and discussed under a Tier 2 risk assessment.

For groundwater that is within 150m of a surface water body, Tier 1 action levels incorporate stringent chronic surface water goals. This is intended to address potential long-term impacts to sensitive aquatic habitats. Chronic surface water goals can be significantly lower than acute goals and can strongly affect the magnitude of remediation required and the timing of case closure. For example, the chronic, freshwater goal for benzene is 46 ug/L but the acute goal is 1,800 ug/L. **Use of chronic surface water goals as groundwater action levels may be overly conservative for sites adjacent to low quality surface water habitats (e.g., drainage canals) or sites where long-term monitoring has demonstrated that the plume is stable or receding and not likely to discharge into a sensitive aquatic habitat. For these sites, groundwater action levels that incorporate acute rather than chronic surface water goals may be more**

appropriate (refer to action levels for sites >150m from a surface water body in Tables A and B). This is similar to guidance in the 1996 HODOH RBCA document. This should be supported and discussed under a Tier 2 assessment.

Soil Action Levels

Direct Exposure:

- Use of alternative action levels for direct-exposure concerns based on commercial/industrial land use rather than residential land use, as assumed in the Tier 1 EALs (e.g., refer to Table I-2 in Appendix 1, see also Section 2.7);
- Use of alternative action levels for soil that is isolated at depth (e.g., >3m below ground surface) or under a permanent cap and not likely to be exposed at the ground surface in the foreseeable future (e.g., refer to Table I-3 in Appendix 1, see also Section 2.7);
- Use of alternative chemical toxicity factors;
- Use of alternative target risk levels;

Indoor Air Impacts:

- Use of soil gas and/or indoor air data to more directly evaluate potential impacts;
- Use of alternative chemical toxicity factors or target risk levels.

Groundwater Protection (leaching effects):

- Consideration of alternative, target groundwater levels;
- Use of groundwater monitoring data to evaluate leaching impacts and groundwater quality concerns (most appropriate where main mass of chemical is in contact with groundwater);
- Use of laboratory leaching test to evaluate potential groundwater impacts (see Section 3.3.3).

Ecological Impact Concerns:

- Use of alternative action levels based on site studies or published data;
- Reconsideration of need to include eco-based action levels in highly developed or industrialized areas.

Gross Contamination:

- Use of alternative ceiling levels and/or site-specific observations and considerations for gross contamination concerns (e.g., for soils isolated at depth, refer to Table F-3 in Appendix 1).

General:

- Consideration of method reporting limits or natural background concentrations of a chemical in place of the EAL.

In each of these examples, an alternative screening level is generated for the specified environmental concern and re-compared to site data. Models and assumptions used to generate each of the Tier 1 action levels are discussed in detail in Appendix 1. The format of the Tier 2 Environmental Risk Assessment Report should be similar to that outlined for Tier 1 reports. Adjustments to Tier 1 action levels should be clearly described and justified within the report and additional information included as necessary.

A depth of three meters (approximately 10 feet) is typically used to delineate between "shallow" soils that could at some point be exposed at the ground surface and "deep" soils that are only likely to be temporarily exposed during construction and utility maintenance work (CalEPA 1996a). The potential for deeper soils to be brought to the surface in the future should be evaluated on a site-by-site basis based on planned redevelopment or maintenance activities. Direct-exposure SALs used in the Tier 1 lookup tables may be overly conservative for use as cleanup levels for deep soils or soils that are to be permanently capped under clean fill, pavement or a building. Direct exposure action levels developed for construction and utility worker scenarios may be more appropriate for these scenarios (e.g., refer to Table I-3 in Appendix 1), although this could place significant restrictions on future use of the land. Other potential environmental concerns such as leaching and vapor emissions to indoor air must also be addressed.

Use of a less conservative commercial/industrial land-use scenario may be appropriate for sites where cleanup to residential land use is not practical. Under this scenario, a target excess cancer risk of 10^{-5} is generally acceptable, provided that cumulative risk after closure does not exceed 10^{-5} or in limited cases 10^{-4}. Commercial/industrial action levels for carcinogens in Appendix 1 are based on a target excess cancer risk of 10^{-6} (see action levels for vapor intrusion concerns in Table C series and action levels for direct-exposure concerns in Table I-2). These action levels can be adjusted to a target 10^{-5} risk by simply multiplying the levels by a factor of ten. The lowest of the adjusted action levels for carcinogenic effects and action levels for noncarcinogenic effects are then used to screen site data. This type of approach must be presented and approved in a site-specific environmental risk assessment.

Cleanup and closure under a commercial/industrial land-use scenario places implicit land-use restrictions on the affected property. While this may be considered acceptable for properties currently zoned for such purposes, the need for such restrictions in the

future should be seriously weighed against the cost-benefit of remediating the property to meet the sometimes more conservative but less restrictive EALs for unrestricted land use. Implications for land-use restriction are discussed in more detail in Section 2.7.

3.3 Tier 3 Environmental Risk Assessments

3.3.1 Purpose

Under Tier 3, alternative models and assumptions are used and fully justified to develop a detailed, comprehensive environmental risk assessment. Portions of the Tier 1 models may still be retained for some components of the risk assessment. A detailed review of the preparation of Tier 3 environmental risk assessments is beyond the scope of this document. A few potentially useful methods and some general cautions are highlighted below. Example references for the preparation of Tier 3 risk assessments are provided at the end of this section.

3.3.2 Mass-Balanced Soil Volatilization Factor Model

A good example of a useful, alternative model for evaluating soil direct-exposure concerns is the mass-balanced volatilization factor model provided in the USEPA document *Soil Screening Guidance* (USEPA 1996). This model was used in earlier versions of the USEPA Preliminary Remedial Goals (PRGs) document (pre-1995). The current PRG model, and the model reflected in the soil direct-exposure action levels presented in this document, assumes an infinite thickness of contaminated soil at a site. For highly volatile chemicals such as vinyl chloride and even benzene, this is excessively conservative and would require the presence of tens of meters impacted soil over a large area to be justifiable. The mass-balanced model allows for the input of the actual thickness of impacted soil at a site and can result in substantially less stringent, and more realistic, screening or cleanup levels for direct-exposure concerns. Note, however, that groundwater protection concerns (i.e., soil leaching) or potential indoor-air impacts often drive screening level environmental concerns at sites impacted with highly mobile, volatile chemicals. This concern and others, as appropriate, should be evaluated in conjunction with direct-exposure concerns.

Easy-to-use spreadsheets that incorporate the mass-balanced direct-exposure model are available for downloading from the Hawaii Department of Health website (HIDOH 1996, DETIER2 spreadsheet developed by editor of this document). Care should be taken to ensure that default toxicity factors presented in these and other spreadsheets are up-to-date and consistent with those used in this document (see Appendix 1, Table H).

3.3.3 Laboratory-Based Soil Leaching Tests

Laboratory-based soil leaching tests offer an alternative to the use of conservative, model-derived soil action levels for groundwater protection concerns (refer to Section 3.4 in Appendix 1). These tests may be especially useful for evaluating soils impacted by inorganic chemicals (e.g., metals and salts) and relatively nonsorptive and nonvolatile organic chemicals. Action levels for leaching of metals from soil are specifically excluded from this document. Where releases of metal compounds to soil are identified, groundwater monitoring (if appropriate) and/or laboratory-based leaching tests should be carried out to fully evaluate potential leaching impacts (refer to Section 3.4 of Appendix 1).

The USEPA Synthetic Precipitation Leaching Procedure (SPLP) is one example of laboratory-based soil leaching tests (USEPA 1994). The SPLP test differs from the more commonly referenced Toxicity Characteristic Leaching Procedure (TCLP) for hazardous waste in that it is specifically designed to evaluate the mobility of organic and inorganic compounds in soils. The results of an SPLP test are compared to regulatory levels for disposal of materials in landfills and this is then used to determine the type of landfill most appropriate for disposal of the soil (e.g., lining, leachate collection system requirements, etc.).

The SPLP test was **not** specifically developed to evaluate leaching of chemicals from soil outside of a controlled, landfill environment but can be used to do so with some caveats. From a groundwater protection standpoint, one goal is to predict the dissolved-phase concentration of a chemical in the pore space of a saturated soil sample (i.e. the leachate) through either models or laboratory tests. The SPLP test does **not** directly provide this information. Using the SPLP test method, 100 grams of soil are added to two liters of reagent water, the sample is mixed for a specified period of time, and an extract of the regent water is analyzed for targeted chemicals. The volume of reagent water added to the sample significantly exceeds the volume of the sample pore space. This leads to significant dilution of the potential "leachate" had the volume of added reagent water only been equal to the volume of the sample pore space.

For example, the pore volume of a 100-gram sample of soil with 35% effective porosity is approximately 20 cm^3 (assumes bulk density of 1.8, total volume 57 cm^3). Adding two liters, or 2,000 cm^3, of water to the sample therefore introduces a laboratory-based, leachate "dilution factor" of approximately 100 to the SPLP test results (volume reagent divided by volume sample pore space). Concentrations of chemicals reported under the SPLP test could therefore be up to 100 times less than the dissolved-phase concentration of the chemical in a saturated sample.

The inherent dilution effect of the SPLP test method is only significant for chemicals that are highly mobile and not significantly volatile (or biodegradable). From a fate and transport perspective, the dilution factor inherent in the SPLP test could be considered to

reflect the decrease in chemical concentrations due to resorption, volatilization and dilution as the leachate migrates downward and mixes with groundwater. Based on comparisons of soil leaching models that take these fate and transport considerations into account (e.g., SESOIL, see Appendix 1) and those that don't (e.g., USEPA 1996), the dilution factor inherent in the SPLP test method appears to be adequately conservative for chemicals that are at least moderately sorptive (i.e., sorption coefficient of at least 100 cm^3/g) or highly volatile (i.e., Henry's Constant of at least 0.001 atm-m3/mole.). **For moderately sorptive and/or volatile chemicals, the results of the SPLP test can be directly compared to target groundwater goals.** This includes most of the organic chemicals listed in the EAL lookup tables (refer to Table H in Appendix 1).

Chemicals listed in the EAL document that are not adequately sorptive or volatile to justify unmodified use of the SPLP test method include all inorganic compounds (e.g., metals and perchlorate) as well as acetone, 2,4 dinitrophenol and methyl ethyl ketone (very low sorption coefficients). Other organic chemicals that fail this test but only moderately include bis(2-chloroethyl)ether, bis(2-chloroisopropyl)ether, chloraniline, 1,2 dibromoethane, 2,4 dimethylphenol, 2,4 dinitrotoluene, MTBE, phenol, 1,1,1,2-tetrachloroethane and 1,1,2,2-tetrachloroethane. **For these and other relatively nonsorptive and nonvolatile chemicals not listed in the EAL tables, the results of the SPLP test should be multiplied by a factor of 100 (or a sample-specific factor) to negate the method-related dilution effect.** The sample results can then be adjusted with respect to chemical-specific and site-specific Dilution/Attenuation Factors (DAFs) that take into account volatilization, resorption, degradation and other factors anticipated to reduce the concentrations of chemicals in leachate as the leachate migrates downward and ultimately mixes with groundwater.

Relatively simple DAFs that only address mixing of leachate with groundwater can be calculated using equations provided in the USEPA *Soil Screening Guidance* (USEPA 1996), among other sources. For the Hawai'i, simple leachate/groundwater mixing DAFs for shallow aquifers would typically fall in the range of 5 for silty soils to 20 for sandy soils (e.g., assuming 2m thick shallow aquifer, 30% effective porosity, infiltration rate of 8.0 cm/year (3 inches/year or approximately 15% of total, average rainfall), and hydraulic conductivities of 2m/day and 15m/day, respectively). DAFs could be much higher for areas with fast moving groundwater and/or little infiltration of precipitation and lower in areas with slow moving groundwater and/or greater infiltration of precipitation. Potentially less conservative DAFs that also address resorption, volatilization and other factors can be calculated using more rigorous models such as SESOIL (see Appendix 1).

3.3.4 Tier 3 Environmental Risk Assessments for Parklands

For initial cleanup efforts at sites to be used as parks or wildlife refuges, it is strongly recommended that such areas be remediated to meet unrestricted land use (i.e., assumed residential exposure, target Excess Cancer Risk of one-in-a-million; target Hazard Index of 1.0 and address potential ecological concerns). From a strictly toxicological

standpoint, a typical recreational-use exposure scenario may suggest that substantially higher concentrations of contaminants could be left in place at the site and not pose a threat to human health. Public parks are typically frequented by children, young mothers, elderly people and other groups of people with potentially elevated sensitivities to environmental contaminants, however. In addition, cleanup levels based on recreational land-use scenarios are oftentimes higher (less stringent) than levels that would be allowed for commercial/industrial properties. This intuitively goes against the concept of developing a park as "refuge" for humans and wildlife. Assumption of a limited exposure frequency and duration (e.g., 100 days per year for ten years) also puts an inherent restriction on the number of days and years that an individual can visit the park without exceeding potential health hazards. Long-term, future uses of such properties are also difficult to predict.

In some cases, remediation of proposed parklands to unrestricted land-use standards may not be technically or economically feasible. This should be evaluated on a site-specific basis and receive approval from the overseeing regulatory agency. In such cases, the appropriateness of allowing unrestricted access to the area should be carefully evaluated. This could include the need to impose access restrictions on the property (i.e., based on the exposure assumptions used in the risk assessment) and/or cap impacted soils with a minimal amount of clean fill. It may also be prudent to post signs at the property entrance that warn of potential health hazards (see Section 2.7).

3.3.5 Tier 3 Reference Documents

Potentially useful reference documents for preparation of Tier 3 environmental risk assessments include the following:

Human Health Risk Assessment:

- *Superfund Exposure Assessment Manual* (USEPA 1988)
- *Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual* (Part A) (USEPA 1989a);
- *Soil Screening Guidance: Technical Background Document* (USEPA 1996);
- *CalTOX, A Multimedia Total Exposure Model For Hazardous-Waste Sites* (CalEPA 1994a);
- *Preliminary Endangerment Assessment Guidance Manual* (CalEPA 1994b);
- *Supplemental Guidance For Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities* (CalEPA 1996a);
- *Exposure Factors Handbook* (USEPA 1997a);

- Standard *Provisional Guide for Risk-Based Corrective Action* (ASTM 1995); and
- Assessing the Significance of Subsurface Contaminant Vapor Migration to Enclosed Spaces (Johnson et. al, 1998).

Ecological Risk Assessment:

- *Risk Assessment Guidance for Superfund: Volume II Environmental Evaluation Manual* (USEPA 1989b);
- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997b), and
- *Guidance for Ecological Risk Assessments at Hazardous Waste Sites and Permitted Facilities* (CalEPA 1996a,b).

The above list of references is not intended to be comprehensive. Additional risk assessment guidance should be referred to as needed.

4

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FIGURES

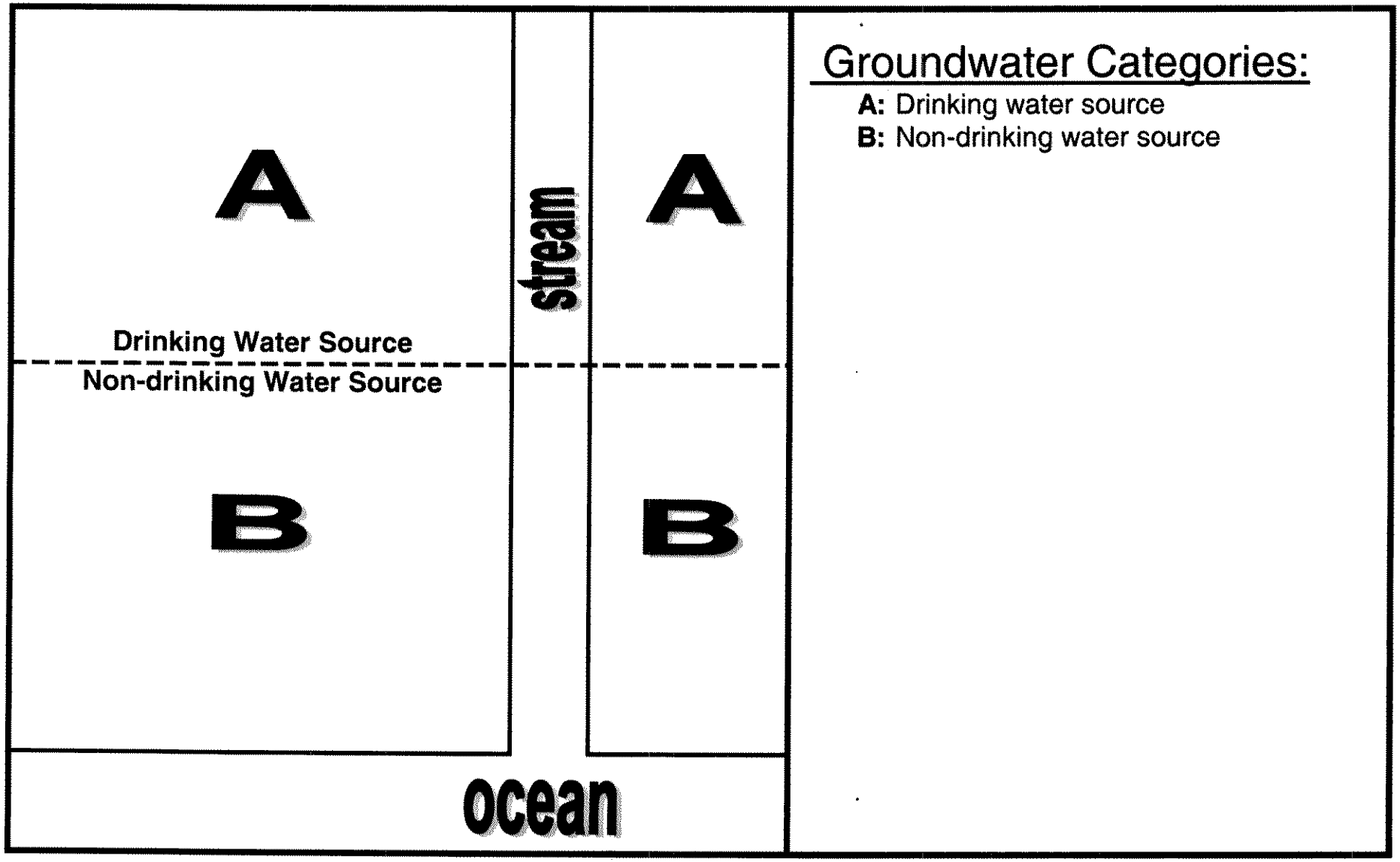

Figure 1. Groundwater zones used in 1996 RBCA lookup tables.

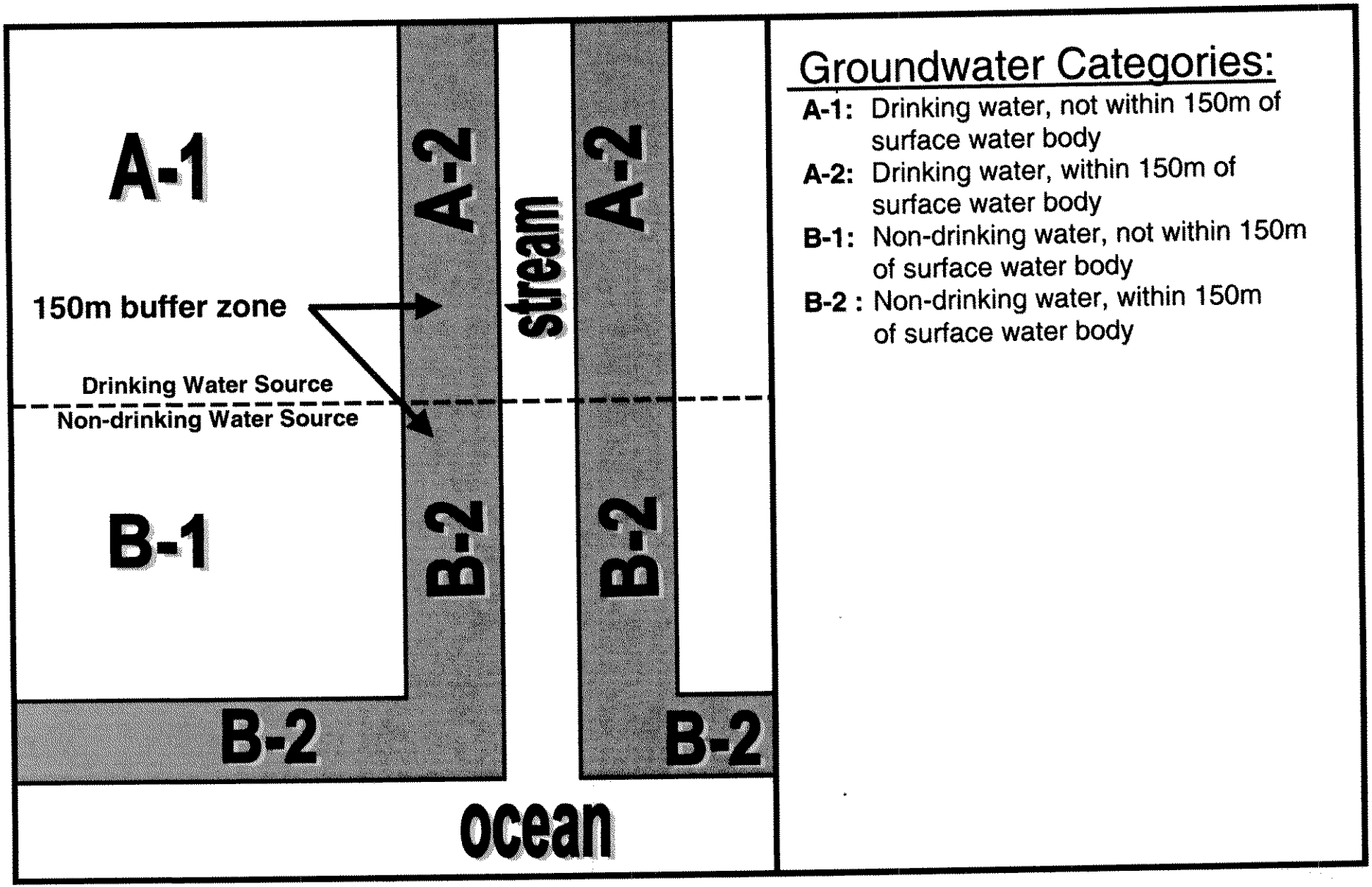

Figure 2. Groundwater zones used in 2003 RBCA lookup tables.

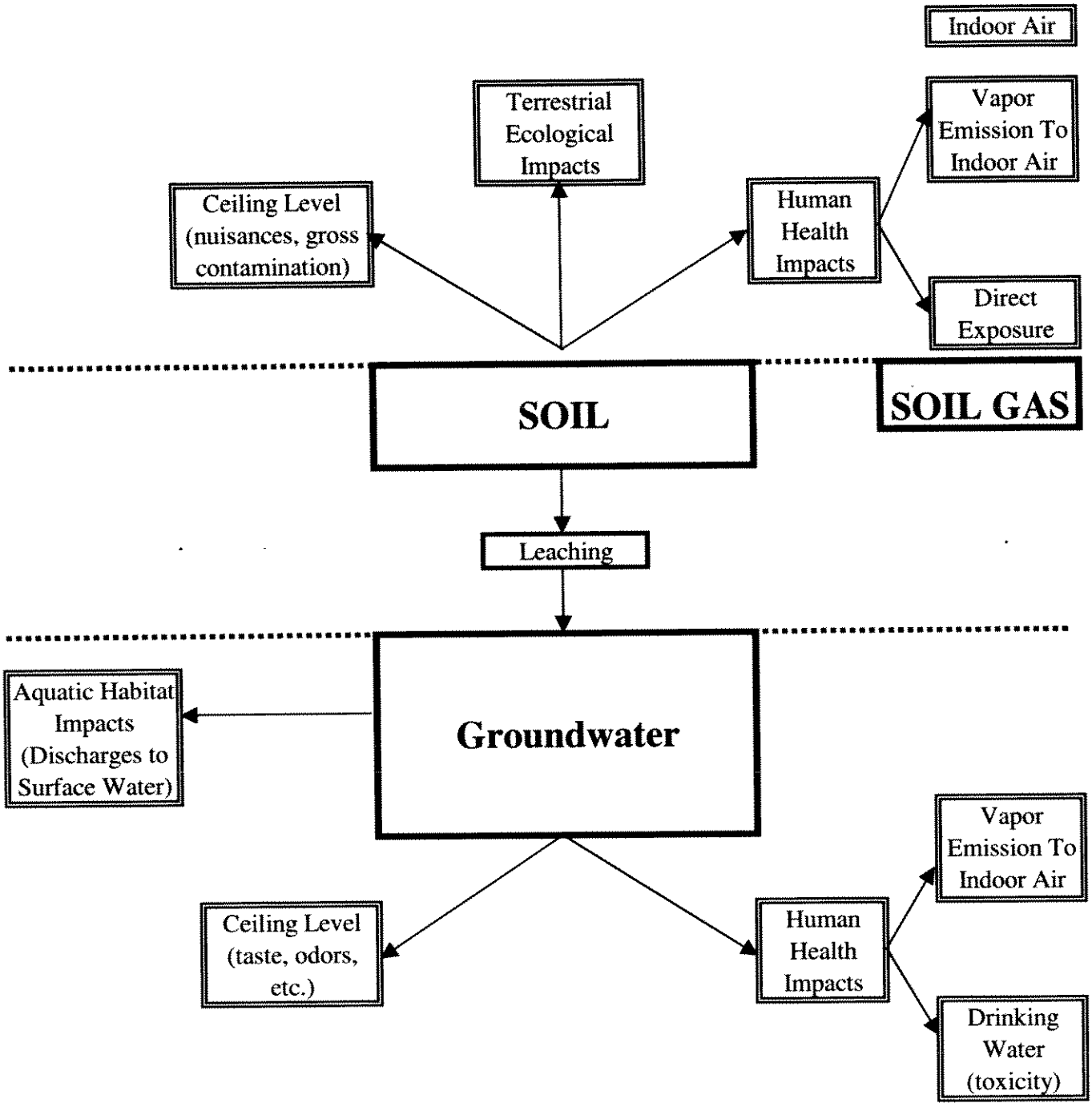

Figure 3. Summary of human health and environmental concerns considered in screening levels. This figure is intended for Tier 1 and Tier 2 assessments only. Evaluation of environmental concerns not shown requires site-specific assessment.

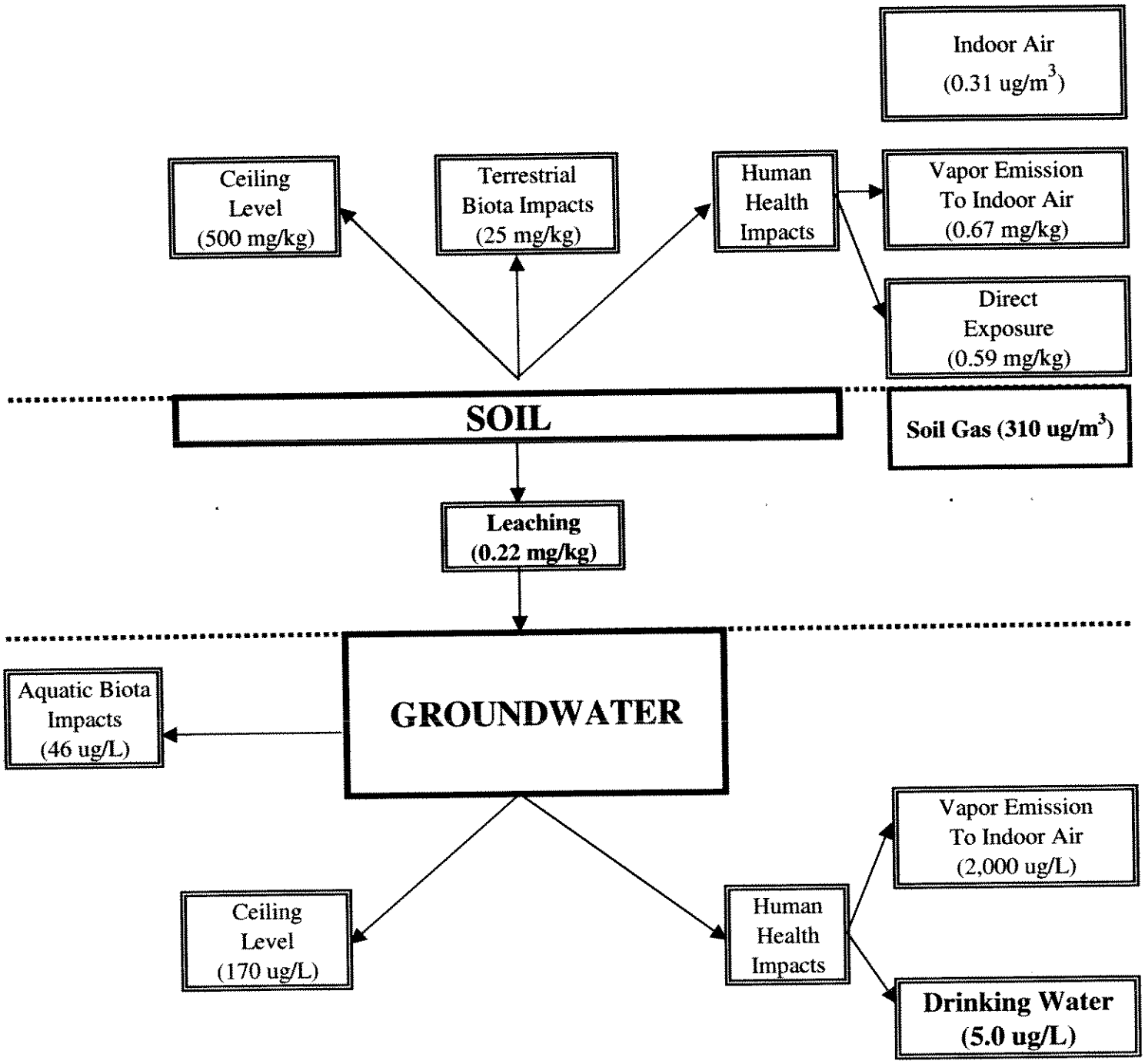

Figure 4. Summary of individual screening levels used to select final, Tier 1 soil and groundwater EALs for benzene (Table A, refer also to Tables A-1 (soil), C-3 (indoor air and soil gas) and D-1a (groundwater) in Appendix 1.

TABLES

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

	>150m to Surface Water Body (A-1)		≤150m to Surface Water Body (A-2)	
CONTAMINANT	Soil (mg/kg)	[3]Groundwater (ug/L)	Soil (mg/kg)	[3]Groundwater (ug/L)
ACENAPHTHENE	1.6E+01	2.0E+01	1.6E+01	2.0E+01
ACENAPHTHYLENE	1.0E+02	2.4E+02	1.3E+01	3.0E+01
ACETONE	2.0E-01	6.1E+02	2.0E-01	6.1E+02
ALDRIN	2.9E-02	4.0E-03	2.9E-02	4.0E-03
ANTHRACENE	2.8E+00	7.3E-01	2.8E+00	7.3E-01
ANTIMONY	2.0E+01	6.0E+00	2.0E+01	6.0E+00
ARSENIC	2.2E+01	1.0E+01	2.2E+01	1.0E+01
BARIUM	7.5E+02	2.0E+03	7.5E+02	2.0E+03
BENZENE	2.2E-01	5.0E+00	2.2E-01	5.0E+00
BENZO(a)ANTHRACENE	6.2E+00	2.7E-02	6.2E+00	2.7E-02
BENZO(b)FLUORANTHENE	6.2E+00	9.2E-02	6.2E+00	9.2E-02
BENZO(k)FLUORANTHENE	3.7E+01	4.0E-01	3.7E+01	4.0E-01
BENZO(g,h,i)PERYLENE	2.7E+01	1.0E-01	2.7E+01	1.0E-01
BENZO(a)PYRENE	6.2E-01	1.4E-02	6.2E-01	1.4E-02
BERYLLIUM	4.0E+00	4.0E+00	4.0E+00	2.7E+00
BIPHENYL, 1,1-	6.5E-01	5.0E-01	6.5E-01	5.0E-01
BIS(2-CHLOROETHYL)ETHER	1.2E-04	9.5E-03	1.2E-04	9.5E-03
BIS(2-CHLOROISOPROPYL)ETHER	3.0E-03	2.7E-01	3.0E-03	2.7E-01
BIS(2-ETHYLHEXYL)PHTHALATE	3.5E+01	6.0E+00	3.5E+01	6.0E+00
BORON	1.6E+00	1.6E+00	1.6E+00	1.6E+00
BROMODICHLOROMETHANE	3.4E-03	1.8E-01	3.4E-03	1.8E-01
BROMOFORM	2.2E+00	1.0E+02	2.2E+00	1.0E+02
BROMOMETHANE	3.4E-01	8.5E+00	3.4E-01	8.5E+00
CADMIUM	1.2E+01	3.0E+00	1.2E+01	3.0E+00
CARBON TETRACHLORIDE	3.5E-02	5.0E+00	3.5E-02	5.0E+00
CHLORDANE	1.6E+00	9.0E-02	1.6E+00	4.0E-03
CHLOROANILINE, p-	5.3E-02	5.0E+00	5.3E-02	5.0E+00
CHLOROBENZENE	3.0E+00	5.0E+01	1.5E+00	2.5E+01
CHLOROETHANE	2.7E-01	3.9E+00	2.7E-01	3.9E+00
CHLOROFORM	6.7E-01	1.0E+02	6.7E-01	1.0E+02
CHLOROMETHANE	2.3E-01	1.5E+00	2.3E-01	1.5E+00
CHLOROPHENOL, 2-	1.2E-02	1.8E-01	1.2E-02	1.8E-01
CHROMIUM (Total)	5.0E+02	7.4E+01	5.0E+02	7.4E+01
CHROMIUM III	7.5E+02	5.7E+02	7.5E+02	7.4E+01
CHROMIUM VI	8.0E+00	1.6E+01	8.0E+00	1.1E+01
CHRYSENE	2.3E+01	3.5E-01	2.3E+01	3.5E-01
COBALT	4.0E+01	3.0E+00	4.0E+01	3.0E+00
COPPER	2.3E+02	2.9E+00	2.3E+02	2.9E+00

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

	>150m to Surface Water Body (A-1)		≤150m to Surface Water Body (A-2)	
CONTAMINANT	Soil (mg/kg)	[3]Groundwater (ug/L)	Soil (mg/kg)	[3]Groundwater (ug/L)
CYANIDE (Free)	1.0E+02	1.0E+00	1.0E+02	1.0E+00
DIBENZO(a,h)ANTHTRACENE	6.2E-01	9.2E-03	6.2E-01	9.2E-03
DIBROMOCHLOROMETHANE	1.1E-02	1.3E-01	1.1E-02	1.3E-01
1,2-DIBROMO-3-CHLOROPROPANE	2.2E-04	4.0E-02	2.2E-04	4.0E-02
DIBROMOETHANE, 1,2-	5.0E-06	7.6E-04	5.0E-06	7.6E-04
DICHLOROBENZENE, 1,2-	1.1E+00	1.0E+01	1.1E+00	1.0E+01
DICHLOROBENZENE, 1,3-	6.3E-01	5.5E+00	6.3E-01	5.5E+00
DICHLOROBENZENE, 1,4-	8.3E-02	5.0E+00	8.3E-02	5.0E+00
DICHLOROBENZIDINE, 3,3-	4.0E-02	1.5E-01	4.0E-02	1.5E-01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.4E+00	2.8E-01	2.4E+00	1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.4E+00	2.8E-01	2.4E+00	1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.7E+00	1.3E-02	1.7E+00	1.0E-03
DICHLOROETHANE, 1,1-	1.9E+00	4.7E+01	1.9E+00	4.7E+01
DICHLOROETHANE, 1,2-	1.1E-03	1.2E-01	1.1E-03	1.2E-01
DICHLOROETHYLENE, 1,1-	1.2E+00	7.0E+00	1.2E+00	7.0E+00
DICHLOROETHYLENE, Cis 1,2-	2.2E+00	7.0E+01	2.2E+00	7.0E+01
DICHLOROETHYLENE, Trans 1,2-	6.7E+00	1.0E+02	6.7E+00	1.0E+02
DICHLOROPHENOL, 2,4-	3.0E-01	3.0E-01	3.0E-01	3.0E-01
DICHLOROPROPANE, 1,2-	2.7E-02	5.0E+00	2.7E-02	5.0E+00
DICHLOROPROPENE, 1,3-	4.6E-02	4.0E-01	4.6E-02	4.0E-01
DIELDRIN	5.2E-03	4.2E-03	2.3E-03	1.9E-03
DIETHYLPHTHALATE	2.2E+01	9.4E+02	3.5E-02	1.5E+00
DIMETHYLPHTHALATE	2.2E+01	9.4E+02	3.5E-02	1.5E+00
DIMETHYLPHENOL, 2,4-	8.2E-01	1.2E+02	7.4E-01	1.1E+02
DINITROPHENOL, 2,4-	2.1E-01	7.3E+01	2.1E-01	7.3E+01
DINITROTOLUENE, 2,4-	2.5E-01	3.4E+01	2.5E-01	3.4E+01
1,4 DIOXANE	3.7E-03	6.1E+00	3.7E-03	6.1E+00
DIOXIN (2,3,7,8-TCDD)	3.9E-06	3.0E-05	3.9E-06	5.0E-06
ENDOSULFAN	1.8E-02	3.4E-02	4.6E-03	8.7E-03
ENDRIN	1.0E-02	3.7E-02	6.5E-04	2.3E-03
ETHYLBENZENE	3.3E+00	3.0E+01	3.3E+00	3.0E+01
FLUORANTHENE	4.0E+01	4.0E+01	4.0E+01	8.0E+00
FLUORENE	1.6E+02	2.4E+02	8.9E+00	3.9E+00
HEPTACHLOR	1.1E-01	5.3E-02	1.3E-02	3.6E-03
HEPTACHLOR EPOXIDE	5.3E-02	5.3E-02	1.4E-02	3.6E-03
HEXACHLOROBENZENE	3.0E-01	1.0E+00	3.0E-01	1.0E+00
HEXACHLOROBUTADIENE	4.3E+00	8.6E-01	4.3E+00	8.6E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	9.8E-02	1.6E-01	4.9E-02	8.0E-02

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

	>150m to Surface Water Body (A-1)		≤150m to Surface Water Body (A-2)	
CONTAMINANT	Soil (mg/kg)	[3]Groundwater (ug/L)	Soil (mg/kg)	[3]Groundwater (ug/L)
HEXACHLOROETHANE	1.6E+01	4.8E+00	1.6E+01	4.8E+00
INDENO(1,2,3-cd)PYRENE	6.2E+00	9.2E-02	6.2E+00	9.2E-02
LEAD	2.0E+02	1.5E+01	2.0E+02	5.6E+00
MERCURY	1.0E+01	2.0E+00	1.0E+01	2.5E-02
METHOXYCHLOR	1.9E+01	3.0E-02	1.9E+01	3.0E-02
METHYLENE CHLORIDE	6.7E-02	4.3E+00	6.7E-02	4.3E+00
METHYL ETHYL KETONE	1.8E+00	1.9E+03	1.8E+00	1.9E+03
METHYL ISOBUTYL KETONE	3.7E+00	1.6E+02	3.7E+00	1.6E+02
METHYL MERCURY	6.1E+00	3.0E-03	6.1E+00	3.0E-03
METHYLNAPHTHALENE (total 1- & 2-)	1.2E+00	1.0E+01	2.5E-01	2.1E+00
METHYL TERT BUTYL ETHER	2.3E-02	5.0E+00	2.3E-02	5.0E+00
MOLYBDENUM	4.0E+01	1.8E+02	4.0E+01	1.8E+02
NAPHTHALENE	1.2E+00	6.2E+00	1.2E+00	6.2E+00
NICKEL	1.5E+02	5.0E+00	1.5E+02	5.0E+00
PENTACHLOROPHENOL	3.0E+00	1.0E+00	3.0E+00	1.0E+00
PERCHLORATE	7.0E-03	3.7E+00	7.0E-03	3.7E+00
PHENANTHRENE	1.8E+01	7.7E+00	1.1E+01	4.6E+00
PHENOL	7.6E-02	5.0E+00	7.6E-02	5.0E+00
POLYCHLORINATED BIPHENYLS (PCBs)	1.1E+00	5.0E-01	1.1E+00	1.4E-02
PYRENE	8.5E+01	2.0E+00	8.5E+01	2.0E+00
SELENIUM	1.0E+01	2.0E+01	1.0E+01	5.0E+00
SILVER	2.0E+01	1.0E+00	2.0E+01	1.0E+00
STYRENE	1.5E+00	1.0E+01	1.5E+00	1.0E+01
tert-BUTYL ALCOHOL	2.3E-02	3.7E+00	2.3E-02	3.7E+00
TETRACHLOROETHANE, 1,1,1,2-	7.6E-03	4.3E-01	7.6E-03	4.3E-01
TETRACHLOROETHANE, 1,1,2,2-	9.9E-04	5.6E-02	9.9E-04	5.6E-02
TETRACHLOROETHYLENE	7.5E-02	5.0E+00	7.5E-02	5.0E+00
THALLIUM	5.2E+00	2.0E+00	5.2E+00	2.0E+00
TOLUENE	2.9E+00	4.0E+01	2.9E+00	4.0E+01
TOXAPHENE	4.0E-01	2.1E-01	4.2E-04	2.0E-04
TPH (gasolines)	1.0E+02/2.0E+03	1.0E+02	1.0E+02/2.0E+03	1.0E+02
TPH (middle distillates)	5.0E+02/5.0E+03	1.0E+02	5.0E+02/5.0E+03	1.0E+02
TPH (residual fuels)	5.0E+02/5.0E+03	1.0E+02	5.0E+02/5.0E+03	1.0E+02
TRICHLOROBENZENE, 1,2,4-	2.1E+01	7.0E+01	7.6E+00	2.5E+01
TRICHLOROETHANE, 1,1,1-	2.5E+01	2.0E+02	7.8E+00	6.2E+01
TRICHLOROETHANE, 1,1,2-	3.3E-02	5.0E+00	3.3E-02	5.0E+00
TRICHLOROETHYLENE	4.7E-03	5.0E+00	4.7E-03	5.0E+00
TRICHLOROPHENOL, 2,4,5-	1.6E+00	1.0E+02	1.8E-01	1.1E+01

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

	>150m to Surface Water Body (A-1)		≤150m to Surface Water Body (A-2)	
CONTAMINANT	Soil (mg/kg)	[3]Groundwater (ug/L)	Soil (mg/kg)	[3]Groundwater (ug/L)
TRICHLOROPHENOL, 2,4,6-	1.2E+00	3.7E+00	1.2E+00	3.7E+00
VANADIUM	2.0E+02	1.9E+01	2.0E+02	1.9E+01
VINYL CHLORIDE	5.8E-02	2.0E+00	5.8E-02	2.0E+00
XYLENES	2.3E+00	2.0E+01	2.3E+00	2.0E+01
ZINC	6.0E+02	2.2E+01	6.0E+02	2.2E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	not applicable	2.0	not applicable
Sodium Adsorption Ratio	5.0	not applicable	5.0	not applicable

Notes:

1. Assumes current or future residenital land use, generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.)
2. Assumes potential impacts to drinking water source and discharge of groundwater into a freshwater, marine or estuary surface water system.

Source of Soil Action Levels: Refer to Appendix 1, Tables A-1 and A-2.
Source of Groundwater Action Levels: Appendix 1, Table D-1a (≤150m to Surface Water Body) and Table D-1b (>150m to Surface Water Body).
Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).
Soil Action Levels intended to address direct-exposure, groundwater protection (leaching), ecologic (urban areas) and nuisance concerns. Soil gas data should be collected for additional evaluation of potential indoor-air impacts at sites with significant areas of VOC-impacted soil. See Section 2.5 and Table C.
Groundwater Action Levels intended to be address drinking water, surface water impacts, indoor-air and nuisance concerns. Use in conjunction with soil gas action levels to more closely evaluate potential impacts to indoor-air if groundwater action levels for this concern approached or exceeded. See Section 2.5 and Table C.
GALs >150m to Surface Water Body: Groundwater screened with respect to acute surface water goals (See Table D-1b).
GALs ≤150m to Surface Water Body: Groundwater screened with respect to chronic surface water goals (see Table D-1a).
TPH -Total Petroleum Hydrocarbons: TPH Action Levels must be used in conjunction with Action Levels for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Volume 1, Section 2.2. TPH Soil Action Levels: First Action Level based on potential nuisance concerns. Second Action Level based on potential leaching concerns. Action Levels for nuisance concerns recommended for soils exposed or potentially exposed at the ground surface (minimum ten feet below ground surface for residential sites with private yards and three feet below ground surface for other land use scenarios.

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body (B-1)		≤150m to Surface Water Body (B-2)	
CONTAMINANT	[2]Soil (mg/kg)	[3]Groundwater (ug/L)	Soil (mg/kg)	[3]Groundwater (ug/L)
ACENAPHTHENE	1.3E+02	2.0E+02	1.9E+01	2.3E+01
ACENAPHTHYLENE	1.3E+02	3.0E+02	1.3E+01	3.0E+01
ACETONE	5.0E-01	1.5E+03	5.0E-01	1.5E+03
ALDRIN	2.9E-02	1.3E+00	2.9E-02	1.3E-01
ANTHRACENE	2.8E+00	7.3E-01	2.8E+00	7.3E-01
ANTIMONY	2.0E+01	1.5E+03	2.0E+01	3.0E+01
ARSENIC	2.2E+01	6.9E+01	2.2E+01	3.6E+01
BARIUM	7.5E+02	2.0E+03	7.5E+02	2.0E+03
BENZENE	5.9E-01	1.7E+03	5.9E-01	4.6E+01
BENZO(a)ANTHRACENE	6.2E+00	2.7E-02	6.2E+00	2.7E-02
BENZO(b)FLUORANTHENE	6.2E+00	9.2E-02	6.2E+00	9.2E-02
BENZO(k)FLUORANTHENE	3.7E+01	4.0E-01	3.7E+01	4.0E-01
BENZO(g,h,i)PERYLENE	2.7E+01	1.0E-01	2.7E+01	1.0E-01
BENZO(a)PYRENE	6.2E-01	1.4E-02	6.2E-01	1.4E-02
BERYLLIUM	4.0E+00	4.3E+01	4.0E+00	2.7E+00
BIPHENYL, 1,1-	6.5E+00	5.0E+00	6.5E+00	5.0E+00
BIS(2-CHLOROETHYL)ETHER	8.8E-03	1.4E+02	8.8E-03	6.1E+01
BIS(2-CHLOROISOPROPYL)ETHER	2.9E+00	3.2E+03	6.6E-01	6.1E+01
BIS(2-ETHYLHEXYL)PHTHALATE	3.5E+01	3.2E+01	3.5E+01	3.2E+01
BORON	1.6E+00	1.6E+00	1.6E+00	1.6E+00
BROMODICHLOROMETHANE	2.9E-02	3.3E+02	2.9E-02	3.3E+02
BROMOFORM	6.1E+01	5.1E+03	6.1E+01	3.2E+03
BROMOMETHANE	1.1E+00	3.0E+03	1.1E+00	1.6E+02
CADMIUM	1.2E+01	3.0E+00	1.2E+01	3.0E+00
CARBON TETRACHLORIDE	3.5E-02	2.7E+01	3.5E-02	9.8E+00
CHLORDANE	1.6E+00	9.0E-02	1.6E+00	4.0E-03
CHLOROANILINE, p-	5.3E-02	5.0E+00	5.3E-02	5.0E+00
CHLOROBENZENE	9.5E+00	1.6E+02	1.5E+00	2.5E+01
CHLOROETHANE	2.7E-01	3.9E+00	2.7E-01	3.9E+00
CHLOROFORM	6.7E-01	2.3E+03	6.7E-01	6.2E+02
CHLOROMETHANE	2.9E-01	1.7E+02	2.9E-01	1.7E+02
CHLOROPHENOL, 2-	1.2E-01	1.8E+00	1.2E-01	1.8E+00
CHROMIUM (Total)	5.0E+02	7.4E+01	5.0E+02	7.4E+01
CHROMIUM III	7.5E+02	5.7E+02	7.5E+02	7.4E+01
CHROMIUM VI	8.0E+00	1.6E+01	8.0E+00	1.1E+01
CHRYSENE	2.3E+01	3.5E-01	2.3E+01	3.5E-01
COBALT	4.0E+01	3.0E+00	4.0E+01	3.0E+00
COPPER	2.3E+02	2.9E+00	2.3E+02	2.9E+00

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body (B-1)		≤150m to Surface Water Body (B-2)	
CONTAMINANT	[2]Soil (mg/kg)	[3]Groundwater (ug/L)	Soil (mg/kg)	[3]Groundwater (ug/L)
CYANIDE (Free)	1.0E+02	1.0E+00	1.0E+02	1.0E+00
DIBENZO(a,h)ANTHTRACENE	6.2E-01	2.5E-01	6.2E-01	2.5E-01
DIBROMOCHLOROMETHANE	2.2E-02	2.0E+02	2.2E-02	2.0E+02
1,2-DIBROMO-3-CHLOROPROPANE	2.2E-04	4.0E-02	2.2E-04	4.0E-02
DIBROMOETHANE, 1,2-	2.4E-03	5.3E+01	2.4E-03	5.3E+01
DICHLOROBENZENE, 1,2-	1.1E+01	1.0E+02	1.6E+00	1.4E+01
DICHLOROBENZENE, 1,3-	1.6E+01	3.7E+02	7.4E+00	6.5E+01
DICHLOROBENZENE, 1,4-	8.3E-02	1.1E+02	8.3E-02	1.5E+01
DICHLOROBENZIDINE, 3,3-	1.1E+00	2.5E+02	1.1E+00	2.5E+02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.4E+00	6.0E-01	2.4E+00	1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.4E+00	1.4E+01	2.4E+00	1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.7E+00	1.3E-02	1.7E+00	1.0E-03
DICHLOROETHANE, 1,1-	1.9E+00	4.7E+01	1.9E+00	4.7E+01
DICHLOROETHANE, 1,2-	2.0E-02	1.6E+02	2.0E-02	1.6E+02
DICHLOROETHYLENE, 1,1-	4.5E+01	3.9E+03	4.3E+00	2.5E+01
DICHLOROETHYLENE, Cis 1,2-	7.8E+00	1.2E+04	7.8E+00	5.9E+02
DICHLOROETHYLENE, Trans 1,2-	1.6E+01	2.6E+03	1.6E+01	5.9E+02
DICHLOROPHENOL, 2,4-	3.0E+00	3.0E+00	3.0E+00	3.0E+00
DICHLOROPROPANE, 1,2-	2.7E-02	1.0E+02	2.7E-02	1.0E+02
DICHLOROPROPENE, 1,3-	1.3E-01	2.0E+02	1.3E-01	1.2E+02
DIELDRIN	3.0E-02	7.1E-01	2.3E-03	1.9E-03
DIETHYLPHTHALATE	2.2E+01	9.4E+02	3.5E-02	1.5E+00
DIMETHYLPHTHALATE	2.2E+01	9.4E+02	3.5E-02	1.5E+00
DIMETHYLPHENOL, 2,4-	1.8E+00	2.7E+02	7.4E-01	1.1E+02
DINITROPHENOL, 2,4-	6.5E-01	2.3E+02	2.1E-01	7.5E+01
DINITROTOLUENE, 2,4-	1.5E+00	2.0E+02	8.6E-01	1.2E+02
1,4 DIOXANE	3.0E+01	5.0E+04	3.0E+01	5.0E+04
DIOXIN (2,3,7,8-TCDD)	3.9E-06	3.0E-03	3.9E-06	5.0E-06
ENDOSULFAN	1.8E-02	3.4E-02	4.6E-03	8.7E-03
ENDRIN	1.0E-02	3.7E-02	6.5E-04	2.3E-03
ETHYLBENZENE	4.7E+00	3.0E+02	4.7E+00	2.9E+02
FLUORANTHENE	4.0E+01	4.0E+01	4.0E+01	8.0E+00
FLUORENE	1.6E+02	3.0E+02	8.9E+00	3.9E+00
HEPTACHLOR	1.1E-01	5.3E-02	1.3E-02	3.6E-03
HEPTACHLOR EPOXIDE	5.3E-02	5.3E-02	1.4E-02	3.6E-03
HEXACHLOROBENZENE	3.0E-01	6.0E+00	3.0E-01	3.7E+00
HEXACHLOROBUTADIENE	6.2E+00	1.1E+01	6.2E+00	4.7E+00
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	9.8E-02	1.6E-01	4.9E-02	8.0E-02

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body (B-1)		≤150m to Surface Water Body (B-2)	
CONTAMINANT	[2]Soil (mg/kg)	[3]Groundwater (ug/L)	Soil (mg/kg)	[3]Groundwater (ug/L)
HEXACHLOROETHANE	3.5E+01	1.0E+02	3.5E+01	1.2E+01
INDENO(1,2,3-cd)PYRENE	6.2E+00	9.2E-02	6.2E+00	9.2E-02
LEAD	2.0E+02	2.9E+01	2.0E+02	5.6E+00
MERCURY	1.0E+01	2.1E+00	1.0E+01	2.5E-02
METHOXYCHLOR	1.9E+01	3.0E-02	1.9E+01	3.0E-02
METHYLENE CHLORIDE	1.1E+00	5.1E+03	1.1E+00	2.2E+03
METHYL ETHYL KETONE	1.3E+01	1.4E+04	1.3E+01	1.4E+04
METHYL ISOBUTYL KETONE	3.9E+00	1.7E+02	3.9E+00	1.7E+02
METHYL MERCURY	6.1E+00	3.0E-03	6.1E+00	3.0E-03
METHYLNAPHTHALENE (total 1- & 2-)	1.2E+01	1.0E+02	2.5E-01	2.1E+00
METHYL TERT BUTYL ETHER	5.2E+00	1.8E+03	5.2E+00	1.8E+03
MOLYBDENUM	4.0E+01	2.4E+02	4.0E+01	2.4E+02
NAPHTHALENE	2.3E+01	2.1E+02	4.8E+00	2.4E+01
NICKEL	1.5E+02	5.0E+00	1.5E+02	5.0E+00
PENTACHLOROPHENOL	3.0E+00	1.3E+01	3.0E+00	7.9E+00
PERCHLORATE	1.2E+00	6.0E+02	1.2E+00	6.0E+02
PHENANTHRENE	1.8E+01	7.7E+00	1.1E+01	4.6E+00
PHENOL	4.0E+01	3.4E+03	1.9E+01	1.3E+03
POLYCHLORINATED BIPHENYLS (PCBs)	1.1E+00	2.0E+00	1.1E+00	1.4E-02
PYRENE	8.5E+01	2.0E+00	8.5E+01	2.0E+00
SELENIUM	1.0E+01	2.0E+01	1.0E+01	5.0E+00
SILVER	2.0E+01	1.0E+00	2.0E+01	1.0E+00
STYRENE	1.5E+01	1.0E+02	1.5E+01	1.0E+02
tert-BUTYL ALCOHOL	7.0E+01	5.0E+04	7.0E+01	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	3.1E+00	3.1E+03	3.1E+00	3.1E+02
TETRACHLOROETHANE, 1,1,2,2-	9.0E-03	1.9E+02	9.0E-03	1.9E+02
TETRACHLOROETHYLENE	7.5E-02	1.1E+02	7.5E-02	1.1E+02
THALLIUM	5.2E+00	4.7E+02	5.2E+00	2.0E+01
TOLUENE	2.9E+01	4.0E+02	9.3E+00	1.3E+02
TOXAPHENE	4.0E-01	2.1E-01	4.2E-04	2.0E-04
TPH (gasolines)	1.0E+02/2.0E+03	5.0E+03	1.0E+02/2.0E+03	5.0E+02
TPH (middle distillates)	5.0E+02/5.0E+03	2.5E+03	5.0E+02/5.0E+03	6.4E+02
TPH (residual fuels)	5.0E+02/5.0E+03	2.5E+03	5.0E+02/5.0E+03	6.4E+02
TRICHLOROBENZENE, 1,2,4-	3.0E+01	1.6E+02	7.6E+00	2.5E+01
TRICHLOROETHANE, 1,1,1-	2.1E+02	6.0E+03	7.8E+00	6.2E+01
TRICHLOROETHANE, 1,1,2-	3.3E-02	3.5E+02	3.3E-02	3.5E+02
TRICHLOROETHYLENE	4.7E-03	9.7E+01	4.7E-03	9.7E+01
TRICHLOROPHENOL, 2,4,5-	1.6E+00	1.0E+02	1.8E-01	1.1E+01

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body (B-1)		≤150m to Surface Water Body (B-2)	
CONTAMINANT	[2]Soil (mg/kg)	[3]Groundwater (ug/L)	Soil (mg/kg)	[3]Groundwater (ug/L)
TRICHLOROPHENOL, 2,4,6-	6.1E+00	4.9E+02	6.1E+00	4.9E+02
VANADIUM	2.0E+02	1.9E+01	2.0E+02	1.9E+01
VINYL CHLORIDE	5.8E-02	3.3E+01	5.8E-02	3.3E+01
XYLENES	2.1E+02	2.0E+03	1.1E+01	1.0E+02
ZINC	6.0E+02	2.2E+01	6.0E+02	2.2E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	not applicable	2.0	not applicable
Sodium Adsorption Ratio	5.0	not applicable	5.0	not applicable

Notes:

1. Assumes current or future residenital land use, generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.)
2. Assumes potential discharge of groundwater into a freshwater, marine or estuary surface water system.

Source of Soil Action Levels: Refer to Appendix 1, Tables B-1 and B-2.
Source of Groundwater Action Levels: Appendix 1, Table D-1c (≤150m to Surface Water Body) and Table D-1d (>150m to Surface Water Body).
Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).
Soil Action Levels intended to address direct-exposure, groundwater protection (leaching), ecologic (urban areas) and nuisance concerns. Soil gas data should be collected for additional evaluation of potential indoor-air impacts at sites with significant areas of VOC-impacted soil. See Section 2.5 and Table C.
Groundwater Action Levels intended to be address surface water impacts, indoor-air and nuisance concerns. Use in conjunction with soil gas action levels to more closely evaluate potential impacts to indoor-air if groundwater action levels for this concern approached or exceeded. See **Section 2.5 and Table C.**
GALs >150m to Surface Water Body: Groundwater screened with respect to acute surface water goals (See Table D-1d).
GALs ≤150m to Surface Water Body: Groundwater screened with respect to chronic surface water goals (see Table D-1c).
TPH -Total Petroleum Hydrocarbons: TPH Action Levels must be used in conjunction with Action Levels for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Volume 1, Section 2.2. TPH Soil Action Levels: First Action Level based on potential nuisance concerns. Second Action Level based on potential leaching concerns. Action Levels for nuisance concerns recommended for soils exposed or potentially exposed at the ground surface (minimum ten feet below ground surface for residential sites with private yards and three feet below ground surface for other land use scenarios.

TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Gas

	INDOOR AIR ACTION LEVELS		[2]SHALLOW SOIL GAS ACTION LEVELS	
CONTAMINANT	[1]Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use Only (ug/m^3)	[1]Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use Only (ug/m^3)
ACENAPHTHENE	2.2E+02	3.1E+02	2.2E+05	6.1E+05
ACENAPHTHYLENE	1.5E+02	2.0E+02	1.5E+05	4.1E+05
ACETONE	3.7E+02	5.1E+02	3.7E+05	1.0E+06
ALDRIN	-	-	-	-
ANTHRACENE	1.1E+03	1.6E+03	1.1E+06	3.2E+06
ANTIMONY	-	-	-	-
ARSENIC	-	-	-	-
BARIUM	-	-	-	-
BENZENE	3.1E-01	5.2E-01	3.1E+02	1.0E+03
BENZO(a)ANTHRACENE	-	-	-	-
BENZO(b)FLUORANTHENE	-	-	-	-
BENZO(k)FLUORANTHENE	-	-	-	-
BENZO(g,h,i)PERYLENE	-	-	-	-
BENZO(a)PYRENE	-	-	-	-
BERYLLIUM	-	-	-	-
BIPHENYL, 1,1-	1.8E+02	2.6E+02	1.8E+05	5.1E+05
BIS(2-CHLOROETHYL)ETHER	7.4E-03	1.2E-02	7.4E+00	2.5E+01
BIS(2-CHLOROISOPROPYL)ETHER	2.4E-01	4.1E-01	2.4E+02	8.2E+02
BIS(2-ETHYLHEXYL)PHTHALATE	-	-	-	-
BORON	-	-	-	-
BROMODICHLOROMETHANE	1.4E-01	2.3E-01	1.4E+02	4.5E+02
BROMOFORM	-	-	-	-
BROMOMETHANE	5.1E+00	7.2E+00	5.1E+03	1.4E+04
CADMIUM	-	-	-	-
CARBON TETRACHLORIDE	1.6E-01	2.7E-01	1.6E+02	5.5E+02
CHLORDANE	-	-	-	-
CHLOROANILINE, p-	-	-	-	-
CHLOROBENZENE	6.3E+01	8.8E+01	6.3E+04	1.8E+05
CHLOROETHANE	2.9E+00	4.9E+00	2.9E+03	9.9E+03
CHLOROFORM	3.1E+00	4.4E+00	3.1E+03	8.8E+03
CHLOROMETHANE	1.4E+00	2.3E+00	1.4E+03	4.5E+03
CHLOROPHENOL, 2-	1.9E+01	2.6E+01	1.9E+04	5.3E+04
CHROMIUM (Total)	-	-	-	-
CHROMIUM III	-	-	-	-
CHROMIUM VI	-	-	-	-
CHRYSENE	-	-	-	-
COBALT	-	-	-	-
COPPER	-	-	-	-
CYANIDE (Free)	-	-	-	-
DIBENZO(a,h)ANTHTRACENE	-	-	-	-
DIBROMOCHLOROMETHANE	1.0E-01	1.7E-01	1.0E+02	3.4E+02
1,2-DIBROMO-3-CHLOROPROPANE	2.1E-01	2.9E-01	2.1E+02	5.8E+02
DIBROMOETHANE, 1,2-	1.1E-02	1.9E-02	1.1E+01	3.7E+01

TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Gas

	INDOOR AIR ACTION LEVELS		[2]SHALLOW SOIL GAS ACTION LEVELS	
CONTAMINANT	[1]Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use Only (ug/m^3)	[1]Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use Only (ug/m^3)
DICHLOROBENZENE, 1,2-	2.1E+02	2.9E+02	2.1E+05	5.8E+05
DICHLOROBENZENE, 1,3-	3.3E+00	4.7E+00	3.3E+03	9.3E+03
DICHLOROBENZENE, 1,4-	3.9E-01	6.5E-01	3.9E+02	1.3E+03
DICHLOROBENZIDINE, 3,3-	-	-	-	-
DICHLORODIPHENYLDICHLOROETHANE (DDD)	-	-	-	-
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	-	-	-	-
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	-	-	-	-
DICHLOROETHANE, 1,1-	5.2E+02	7.3E+02	5.2E+05	1.5E+06
DICHLOROETHANE, 1,2-	9.4E-02	1.6E-01	9.4E+01	3.1E+02
DICHLOROETHYLENE, 1,1-	2.1E+02	2.9E+02	2.1E+05	5.8E+05
DICHLOROETHYLENE, Cis 1,2-	3.7E+01	5.1E+01	3.7E+04	1.0E+05
DICHLOROETHYLENE, Trans 1,2-	7.3E+01	1.0E+02	7.3E+04	2.0E+05
DICHLOROPHENOL, 2,4-	-	-	-	-
DICHLOROPROPANE, 1,2-	1.3E-01	2.2E-01	1.3E+02	4.3E+02
DICHLOROPROPENE, 1,3-	6.1E-01	1.0E+00	6.1E+02	2.0E+03
DIELDRIN	-	-	-	-
DIETHYLPHTHALATE	-	-	-	-
DIMETHYLPHTHALATE	-	-	-	-
DIMETHYLPHENOL, 2,4-	7.3E+01	1.0E+02	7.3E+04	2.0E+05
DINITROPHENOL, 2,4-	-	-	-	-
DINITROTOLUENE, 2,4-	-	-	-	-
1,4 DIOXANE	-	-	-	-
DIOXIN (2,3,7,8-TCDD)	-	-	-	-
ENDOSULFAN	-	-	-	-
ENDRIN	-	-	-	-
ETHYLBENZENE	2.2E+00	3.7E+00	2.2E+03	7.4E+03
FLUORANTHENE	-	-	-	-
FLUORENE	1.5E+02	2.0E+02	1.5E+05	4.1E+05
HEPTACHLOR	-	-	-	-
HEPTACHLOR EPOXIDE	-	-	-	-
HEXACHLOROBENZENE	-	-	-	-
HEXACHLOROBUTADIENE	-	-	-	-
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	-	-	-	-
HEXACHLOROETHANE	-	-	-	-
INDENO(1,2,3-cd)PYRENE	-	-	-	-
LEAD	-	-	-	-
MERCURY	-	-	-	-
METHOXYCHLOR	-	-	-	-
METHYLENE CHLORIDE	5.2E+00	8.7E+00	5.2E+03	1.7E+04
METHYL ETHYL KETONE	1.0E+03	1.5E+03	1.0E+06	2.9E+06
METHYL ISOBUTYL KETONE	8.4E+01	1.2E+02	8.4E+04	2.4E+05
METHYL MERCURY	-	-	-	-
METHYLNAPHTHALENE (total 1- & 2-)	1.5E+02	2.0E+02	1.5E+05	4.1E+05

TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Gas

	INDOOR AIR ACTION LEVELS		[2]SHALLOW SOIL GAS ACTION LEVELS	
CONTAMINANT	[1]Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use Only (ug/m^3)	[1]Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use Only (ug/m^3)
METHYL TERT BUTYL ETHER	2.4E+01	4.1E+01	2.4E+04	8.2E+04
MOLYBDENUM	-	-	-	-
NAPHTHALENE	3.1E+00	4.4E+00	3.1E+03	8.8E+03
NICKEL	-	-	-	-
PENTACHLOROPHENOL	-	-	-	-
PERCHLORATE	-	-	-	-
PHENANTHRENE	1.5E+02	2.0E+02	1.5E+05	4.1E+05
PHENOL	-	-	-	-
POLYCHLORINATED BIPHENYLS (PCBs)	-	-	-	-
PYRENE	1.1E+02	1.6E+02	1.1E+05	3.2E+05
SELENIUM	-	-	-	-
SILVER	-	-	-	-
STYRENE	1.0E+03	1.5E+03	1.0E+06	2.9E+06
tert-BUTYL ALCOHOL	2.8E+00	4.8E+00	2.8E+03	9.5E+03
TETRACHLOROETHANE, 1,1,1,2-	3.3E-01	5.5E-01	3.3E+02	1.1E+03
TETRACHLOROETHANE, 1,1,2,2-	4.2E-02	7.0E-02	4.2E+01	1.4E+02
TETRACHLOROETHYLENE	3.5E-01	5.9E-01	3.5E+02	1.2E+03
THALLIUM	-	-	-	-
TOLUENE	4.2E+02	5.8E+02	4.2E+05	1.2E+06
TOXAPHENE	-	-	-	-
TPH (gasolines)	5.2E+01	7.3E+01	5.2E+04	1.5E+05
TPH (middle distillates)	5.2E+01	7.3E+01	5.2E+04	1.5E+05
TPH (residual fuels)	-	-	-	-
TRICHLOROBENZENE, 1,2,4-	2.1E+02	2.9E+02	2.1E+05	5.8E+05
TRICHLOROETHANE, 1,1,1-	2.3E+02	3.2E+02	2.3E+05	6.4E+05
TRICHLOROETHANE, 1,1,2-	1.5E-01	2.6E-01	1.5E+02	5.1E+02
TRICHLOROETHYLENE	2.2E-02	3.7E-02	2.2E+01	7.4E+01
TRICHLOROPHENOL, 2,4,5-	3.7E+02	5.1E+02	3.7E+05	1.0E+06
TRICHLOROPHENOL, 2,4,6-	-	-	-	-
VANADIUM	-	-	-	-
VINYL CHLORIDE	2.7E-01	4.6E-01	2.7E+02	9.2E+02
XYLENES	1.0E+02	1.5E+02	1.0E+05	2.9E+05
ZINC	-	-	-	-

TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Gas

CONTAMINANT	INDOOR AIR ACTION LEVELS		[2]SHALLOW SOIL GAS ACTION LEVELS	
	[1]Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use Only (ug/m^3)	[1]Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use Only (ug/m^3)
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	not applicable	not apploicable	not applicable
Sodium Adsorption Ratio	not applicable	not applicable	not applicable	not applicable

Notes:

1. Category "Residential Land Use" generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.)
2. Soil Gas: Action levels based on soil gas data collected less than 1.5 meters (five feet) below a building foundation or the ground surface. Intended for evaluation of potential indoor-air impacts.

Source of Action Levels: Refer to Tables C-2 and C-3 in Appendix 1.

TPH -Total Petroleum Hydrocarbons. TPH EALs must be used in conjunction with EALs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Volume 1, Section 2.2 and Appendix 1, Chapter 5.